Future changes of the Kuroshio and the Kuroshio Extension in eddy-resolving climate models

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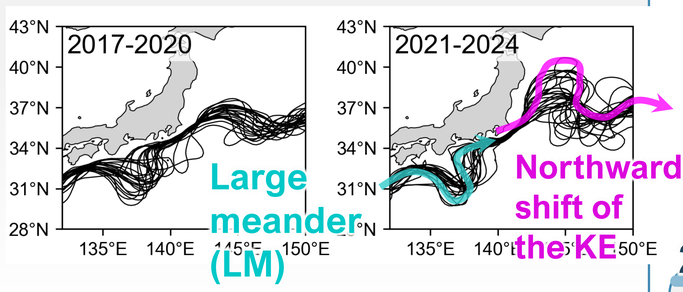
1. Introduction

Main Question

How do the Kuroshio and Kuroshio Extension (KE) change under global warming in eddy-resolving climate models?

Motivation

- **Poleward shifts** of major subtropical western boundary currents (WBCs) are observed by satellite altimetry.
  - However, **strong natural variability** is contained.
- Low-resolution models lack reproducibility in WBCs.
- Large uncertainty of future projections exists in the Northern Hemisphere.



Summary

- **The Kuroshio Extension shifts slightly equatorward** in CESM-HR future-scenario simulation.
- **Future suppression of the Kuroshio large meander** contributes to the equatorward shift of the Kuroshio Extension.
  - **Persistence of LM decreases** rather than decrease in its occurrences.
- **Enhanced stratification weakens the interfacial beta effect**, which contributes to decrease in persistence of the LM.

2. Model & Data

★**CESM-HR, 10-member ensemble simulations** (Chang et al. 2020)

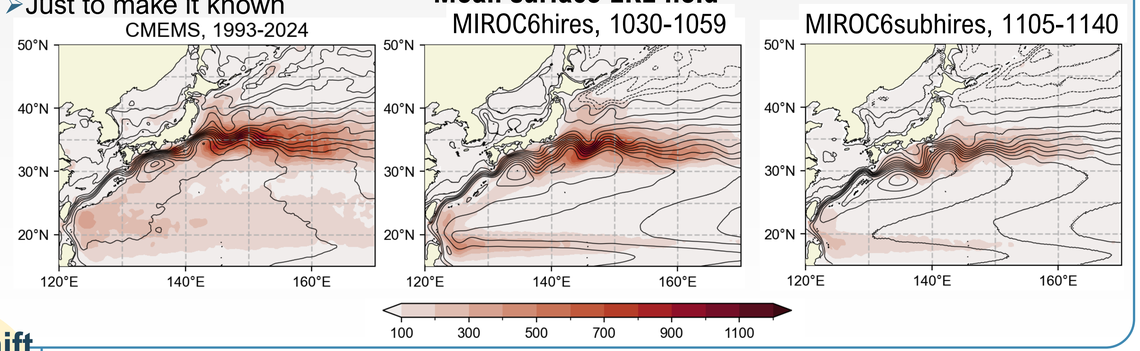
- **HIST (1920-2005), RCP8.5 (2006-2100)**
- Ensemble-mean changes from **P1(1920-1969) to P2 (2051-2100)** are investigated.

●MIROC6 CGCM hires/subhires/standard (Tatebe et al. 2018)

- Hires is under development.
- Just to make it known

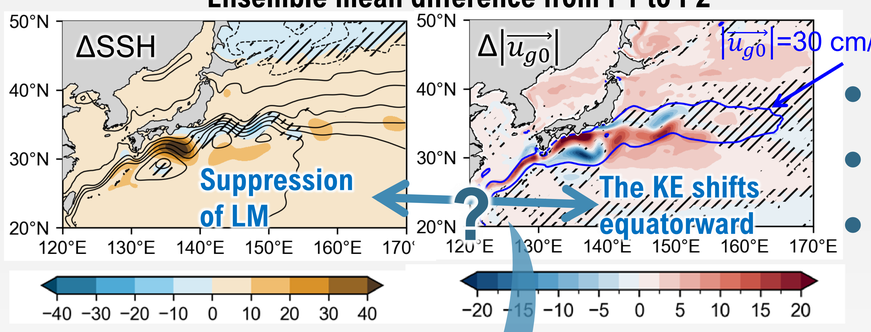
		AGCM OGCM	Horizontal resolution
CESM-HR	Atmos.	CAM5	~0.25º
	Ocean	POP2	~0.1º
CESM-LR	Atmos.	CAM5	~1º
	Ocean	POP2	~1º
MIROC6	Atmos	MIROC6	~1.5º
	OCEAN	COCOv5	~0.1º

Mean surface EKE field



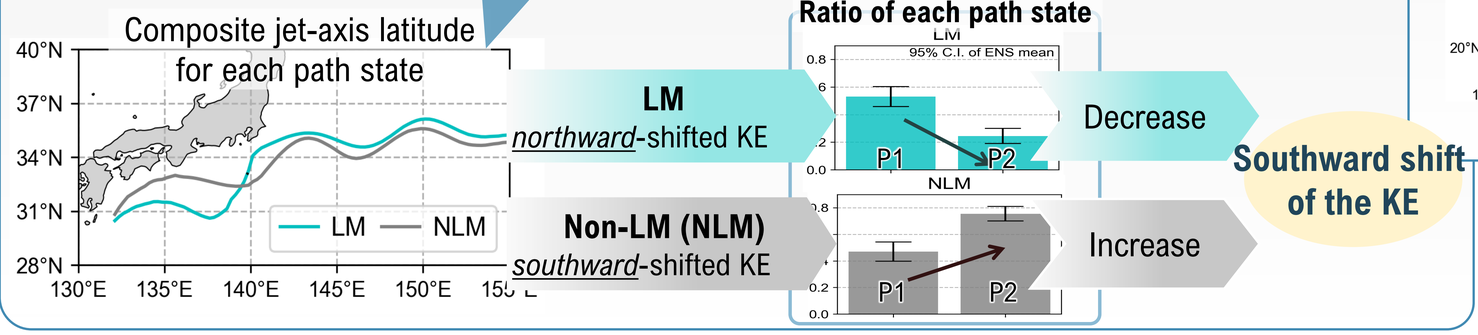
3.1 KE southward shift in CESM-HR

Ensemble mean difference from P1 to P2



- WBCs in the Southern Hemisphere shift poleward (not shown).
- The Gulf Stream weakens due to weakening of the AMOC (not shown).
- The KE shifts **slightly equatorward** associated with the LM suppression
  - The KE shifts **poleward in CESM-LR** (not shown).

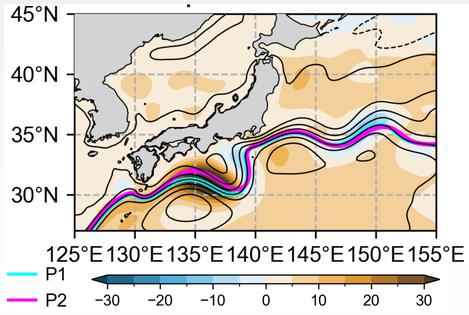
LM suppression contributes to the KE southward shift



3.2 Persistence of the LM decreases

- **Persistence of LM decreases** rather than decrease in LM occurrences (not shown).
- **LM in P2 is located downstream** compared to that in P1.

ΔSSH (P2-P1) conditional on LM



3.3 Weakening of "interfacial" beta effect

- The LM can be regarded as a stationary Rossby wave with background eastward flow (White and McCreary 1986).

Wavelength of a stationary Rossby wave in uniform eastward flow

$$\lambda = 2\pi\sqrt{U/\beta}$$

Eastward advection (U) vs Westward β effect

+ Stretching of water column Kurogi and Akitomo (2006)

$$\lambda = 2\pi\sqrt{U/(\beta+\beta^*)}$$

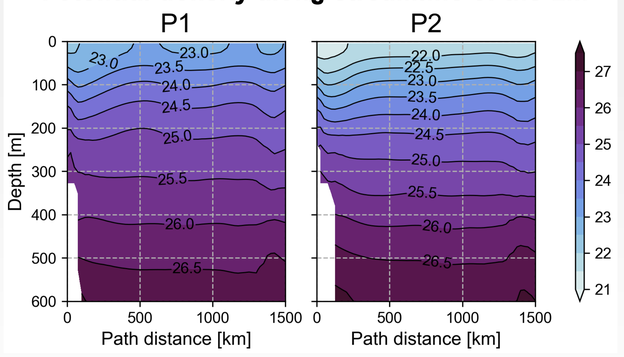
$$\beta^* = -\frac{f^m}{h^m}\frac{\Delta h}{\Delta y}$$

Variation along the streamline

Smaller β^* → Weaker westward tendency, Larger wavelength → **LM is advected downstream**

Upper ocean warms faster → Stronger stratification → Smaller variation in isopycnal depth

Potential density along streamline of the LM



$$\beta^* = -\frac{f^m}{h^m}\frac{\Delta h}{\Delta y}$$

→Smaller

	P1	P2
$\overline{\beta^*}$ [10^{-11} s^{-1} m^{-1}]	4.1 ± 0.7	0.6 ± 0.8
Reference σ_θ	25	24.5