Simulated primary production in the Kuroshio Extension under the influence of the global warming

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Introduction

Kuroshio Extension

Kuroshio-Oyashio transition region
Between the Kuroshio front and the Oyashio front

Kuroshio recirculation region
South the Kuroshio front
Introduction

Region where the Kuroshio front and the Oyashio front are close to each other.

Kuroshio-Oyashio transition region

Nutrient-rich and high density

Nutrient-poor and low density
Introduction

Oyashio

Kuroshio

Region where the Kuroshio front and the Oyashio front are close to each other.

Nutrient-rich and high density

Nutrient-poor and low density

Nutrient limitation

Light limitation

Oyashio water
Introduction

The Kuroshio water runs on the Oyashio water because of its low density.

Nutrient-rich and high density

Nutrient-poor and low density

Nutrient limitation

Light limitation

Oyashio

Kuroshio

Oyashio water
Introduction

Oyashio

Kuroshio

Nutrient limitation

Light limitation

The Kuroshio water runs on the Oyashio water because of its low density.

Layered structure exists in the Kuroshio-Oyashio transition region

Nutrient-rich and high density

Nutrient-poor and low density
Introduction

**Oyashio**

**Kuroshio**

Nutrient-rich and high density

Nutrient-poor and low density

**Nutrient limitation**

**Light limitation**

Light

Nutrients from Oyashio water

Oyashio water
Introduction

Nutrient limitation

Optimum condition for photosynthesis increases the Kuroshio origin phytoplankton

Light limitation

Nutrients from Oyashio water

Oyashio water

Oyashio

Kuroshio

Light

30

35

40

45

50

25

125

130

135

140

145

150

Long (°E)

Lat (°N)
Relationship between the layered structure and the primary production in the KOTR

April–May

Distribution of high chlorophyll-a density (< 0.8 mg/m³) area from 1998 to 2007

Distribution of layered structure from 1998 to 2007

Each distribution resembles each other

Nishikawa et al. (2016)
Relationship between the layered structure and the primary production in the KOTR

Spring primary production in the KOTR is related to the distribution of the layered structure.

Dimension of layered structure and the box mean spring chlorophyll-a density in the KOTR.

(b) < 20% at 50 m & > 50% at 300 m
(R² = 0.90)
How to detect the layered structure

Pure Kuroshio water

Pure Oyashio water

Definition of layered structure
Oyashio mixing ratio < 20% at 50m
Oyashio mixing ratio > 50% at 300m
How to detect the layered structure

Pure Kuroshio water

Pure Oyashio water

Definition of layered structure
Oyashio mixing ratio < 20% at 50m
Oyashio mixing ratio > 50% at 300m

Current TS profiles of the Kuroshio and Oyahsio are effective under the global warming condition?
Purpose of this study

• Redefine the Kuroshio and Oyashio TS profiles on the basis of the results of global warming simulations.

• Estimate the distribution of the layered structure by using newly defined the Kurohsio and Oyashio profiles for discussing the future primary production in the KOTR.
Global warming simulation

The meso-scale global warming simulation
We downscaled a series of OGCM experiments of past to future ocean climate projection in the Northwestern Pacific with 10 km resolution.
  - Historical simulation: 1982–2005
  - Future simulation: 2006–2100

2 models of CMIP5 with 2 RCP scenarios are chosen for the atmospheric forcing.

**MIROC5** (AORI, NIES, JAMSTEC)
**MRI-CGCM3** (Meteorological Research Institute JAPAN)

**RCP2.6 and RCP8.5**

![Graph showing Global Mean Surface Temperature](image)

- **Temperature in 1850**
- **+2°C**
- **+4°C**
Detection of Kuroshio water and Oyashio water

• **Kuroshio water**
  140–160°E, 0–100 km south from the Kuroshio axis

• **Oyashio water**

General definition of the Oyashio water is the 100 m temperature < 5°C (Hanawa and Mitsudera, 1986). But this study, we used the water from the region near **Oyashio formation area** because the Oyashio water temperature and salinity could change by the global warming. We define the TS profiles each year from 2006 to 2100.

Oyashio is mixture of Okhotsk Sea Mode Water and East Kamchatka Current. (Osafune et al., 2006)
Result
Change of TS profiles for the Kuroshio and Oyashio waters

April

MRI-CGCM3

RCP2.6

RCP8.5

MIROC5

Kuroshio

Oyashio

2090
2050
2010

2090
2050
2010
In both models and scenarios, the Kuroshio TS profiles change very little.
In RCP2.6, Oyashio is getting high temperature and high salinity. But this tendency stops in the late 21st century.

In RCP8.5, Oyashio is getting high temperature and high salinity continuously.
**Result**

**Distribution of layered structure (MRI-CGCM3)**

- Thin: year to year variation
- Bold: 10 yrs running mean

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**Historical**

**MRICGCM3**

- Dimension of layered structure ($10^6$ km$^2$)

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**RCP2.6**

**RCP8.5**
Result

Distribution of layered structure (MRI-CGCM3)

Even in the global warming condition, broad distribution of the layered structure still appears.

But in the global warming condition, sometimes the layered structure mostly disappears.

No significant difference is shown between RCP2.6 and RCP8.5.
Result

Distribution of layered structure (MIROC5)

### MIROC5
- **Thin:** year to year variation
- **Bold:** 10 yrs running mean

#### Historical

- **RCP2.6**
- **RCP8.5**

#### Dimension of layered structure ($10^6$ km$^2$)

- 1982
- 1992
- 2002
- 2012
- 2022
- 2032
- 2042
- 2052
- 2062
- 2072
- 2082
- 2092
Result
Distribution of layered structure (MIROC5)

Difference between Historical and RCP scenarios is not large.

Variations of RCP 2.6 and 8.5 are similar before 2080s. Layered structure becomes small in RCP8.5 in 2090s due to the global warming?
Conclusion and Discussion

• **TS Profiles of the Kuroshio and Oyashio**
  TS of Kuroshio is not affected by the global warming. Both TS of Oyashio tend to be high due to progress of the global warming but it stops in RCP2.6.

• **Layered structure distribution**
  In MRI-CGCM3, the distribution decreased in the global warming condition. In MIROC5, the distribution seems to become low in RCP8.5.

**Future spring primary production in the KOTR**
If the result that the global warming decreases the layered structure is correct, the primary production will decrease.
Conclusion and Discussion

• **TS Profiles of the Kuroshio and Oyashio**
  TS of Kuroshio is not affected by the global warming. TS of Oyashio tend to be high due to progress of the global warming but it stops in RCP2.6.

• **Layered structure distribution**
  In MRI-CGCM3, the distribution decreased in the global warming condition. In MIROC5, it seems to become low in RCP8.5 but not clear.

**Future spring primary production in the KOTR**

If the result that the global warming decrease the layered structure is correct, the primary production will decrease.

But note that the high productivity in the layered structure depending on high nutrient density in the Oyashio water.

Since our study suggested the change of characteristic of the Oyashio water, we have to consider the explicit nutrient cycle under the global warming condition in the next step.