The Kuroshio intrusion into the East China Sea revealed by a new mixed-layer water mass analysis

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1. Introduction

- Though the Kuroshio intrusion into the East China Sea (ECS) is relatively weaker during summer, it is of great importance to the ECS shelf ecosystem in this biologically-active season.
- In the southern ECS continent shelf, the surface intrusion is mainly originated from south including the Taiwan Warm Current and the Kuroshio. Their tracer properties may be very close, so it is difficult to distinguish them from each.
- Traditional water mass analysis methods are not suitable for surface layer water since the tracer properties are usually not conservative due to the modification of atmospheric forcing and biogeochemical processes.
- We develop and validate a new tracer-based Mixed-Layer Optimal Multi-Parameter (MLOMP) water mass analysis, which can well capture the intrusion pattern and year-to-year variation.

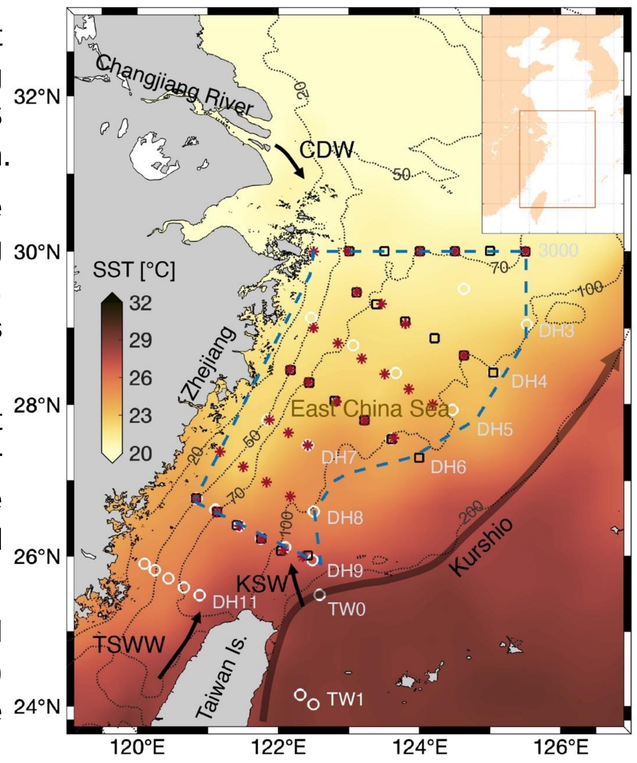

Fig.1. The schematic map of the study area.

2. Method

Optimal Multi-Parameter Water Mass Analysis (OMP)

T is not conservative at surface

$$\begin{cases} X_1T_1 + X_2T_2 + X_3T_3 - T_{obs} = R_T \\ X_1S_1 + X_2S_2 + X_3S_3 - S_{obs} = R_S \\ X_1I_1 + X_2I_2 + X_3I_3 - I_{obs} = R_I \\ X_1A_1 + X_2A_2 + X_3A - A_{obs} = R_A \\ X_1 + X_2 + X_3 - 1 = R_M \end{cases}$$

T_i, S_i, I_i and A_i are temperature, salinity, iodide and iodate of the i th Source Water Types (SWTs).

Mixed-Layer Optimal Multi-Parameter Water Mass Analysis (MLOMP)

$$(T_1 + \Delta T_1)x_1 + (T_2 + \Delta T_2)x_2 + (T_3 + \Delta T_3)x_3 - T_{obs} = R_T$$

atmospheric correction

$$\frac{\Delta T_3}{\Delta T_2} = \frac{t_3}{t_2}$$

$$T_1x_1 + (T_2 + \Delta T_2)x_2 + \left(T_3 + \frac{t_3}{t_2}\Delta T_2\right)x_3 - T_{obs} = R_T$$

Mixed-Layer Water Mass Analysis (MLWMA) —— only T and S

atmospheric correction

$$T_i = T_i^{SWT} + \Delta T_i$$

$$\Delta T_i = \int_{SWT}^{Local} \frac{Q(\xi)}{c_0\rho_0 hv(\xi)}\, d\xi$$

3. Results and Conclusions

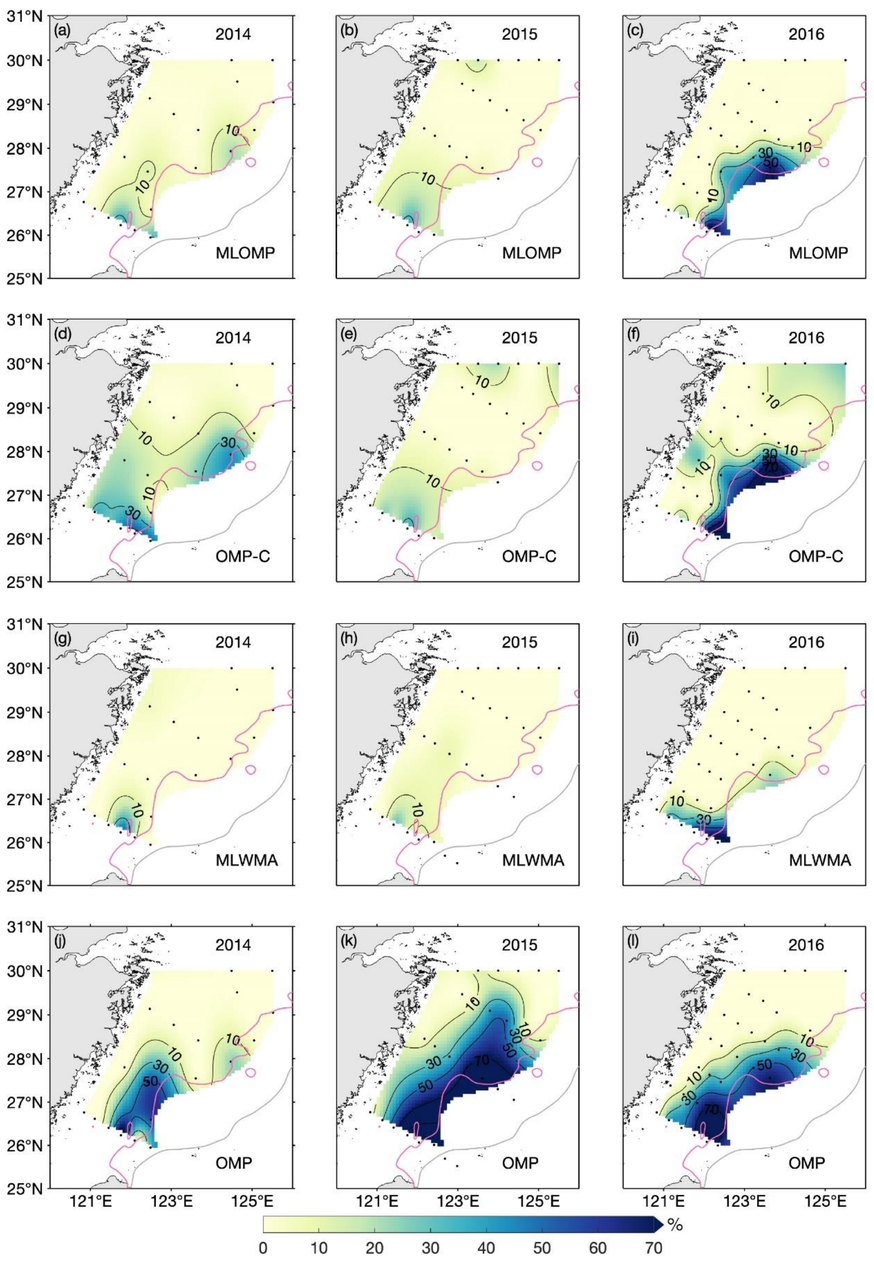

Fig.2. (a, b, c) The KSW composition calculated by the MLOMP, (d, e, f) the original OMP with conservative tracers only (OMP-C), (g, h, i) MLWMA and (j, k, l) OMP (j, k, l). The pink and gray contours are the 100 m and 200 m isobaths respectively.

Year-to-year variability of summer KSW

- The original OMP method may produce a large error if directly applied to the mixed layer water.
- In contrast, the intrusion given by the MLOMP are slightly weaker in both spatial extent and water proportion than that of the OMP-C.
- The MLWMA produces an even weaker intrusion, but it can still generate reasonable distribution patterns compared to the original OMP analysis without more constraints from additional chemical tracers.

Table 1. Three-year KI indices and regionally mean intrusion percentage (IP)

Year	2014	2015	2016
KI Index	0.0365	0.0446	0.1981
MLOMP IP	4.6 %	4.0 %	8.6 %
MLWMA IP	2.0 %	2.5 %	4.1 %

Validation of the water mass analysis results

Relatively small (large) KI anomalies in 2014 and 2015 (in 2016) are associated with the low (high) proportion of the KSW in the water mass analysis, which confirms the weak (strong) surface Kuroshio intrusion revealed by the MLOMP and MLWMA results. The results are consistent with the AVISO satellite-derived geostrophic current (Fig. 3).

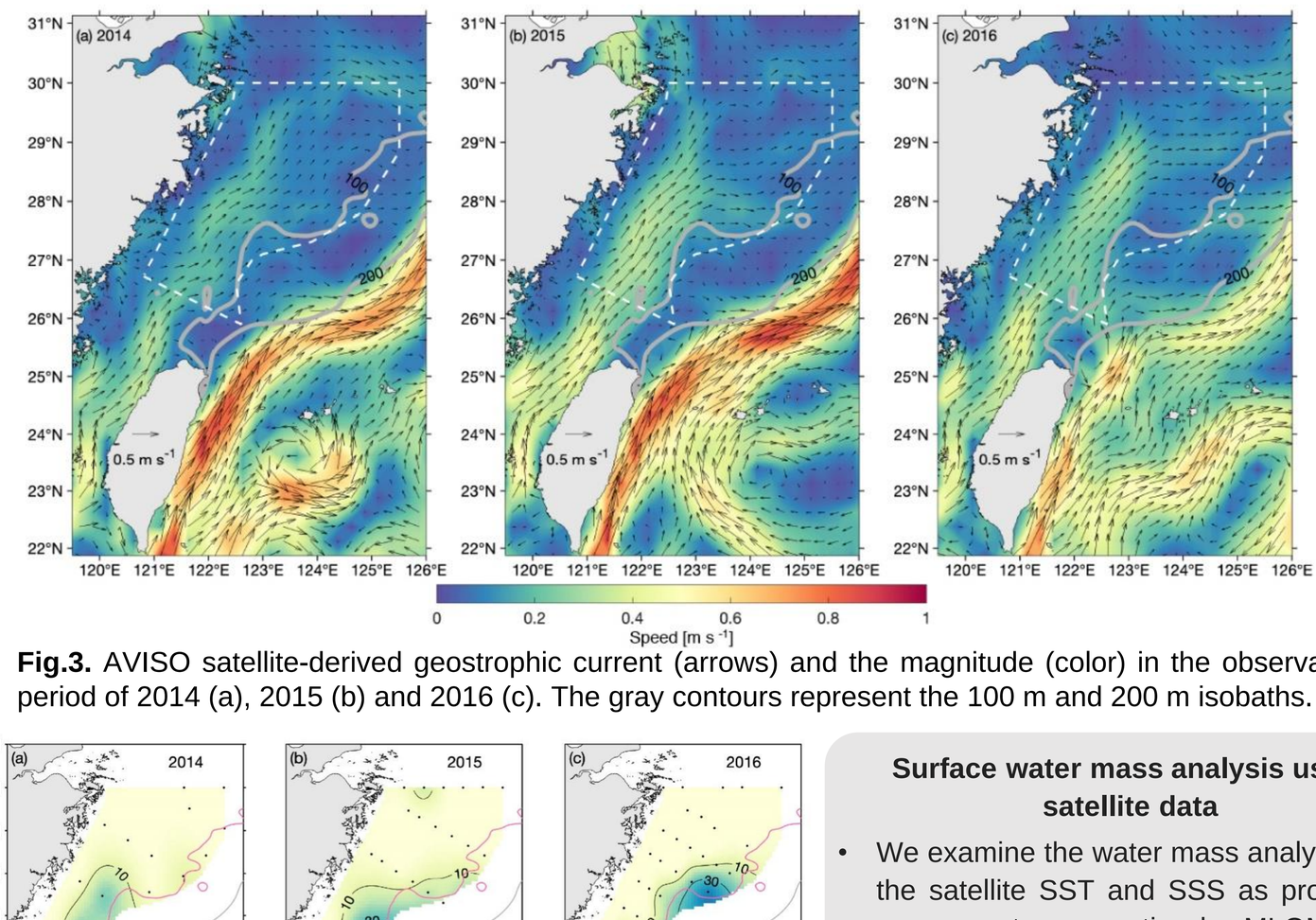

Fig.3. AVISO satellite-derived geostrophic current (arrows) and the magnitude (color) in the observation period of 2014 (a), 2015 (b) and 2016 (c). The gray contours represent the 100 m and 200 m isobaths.

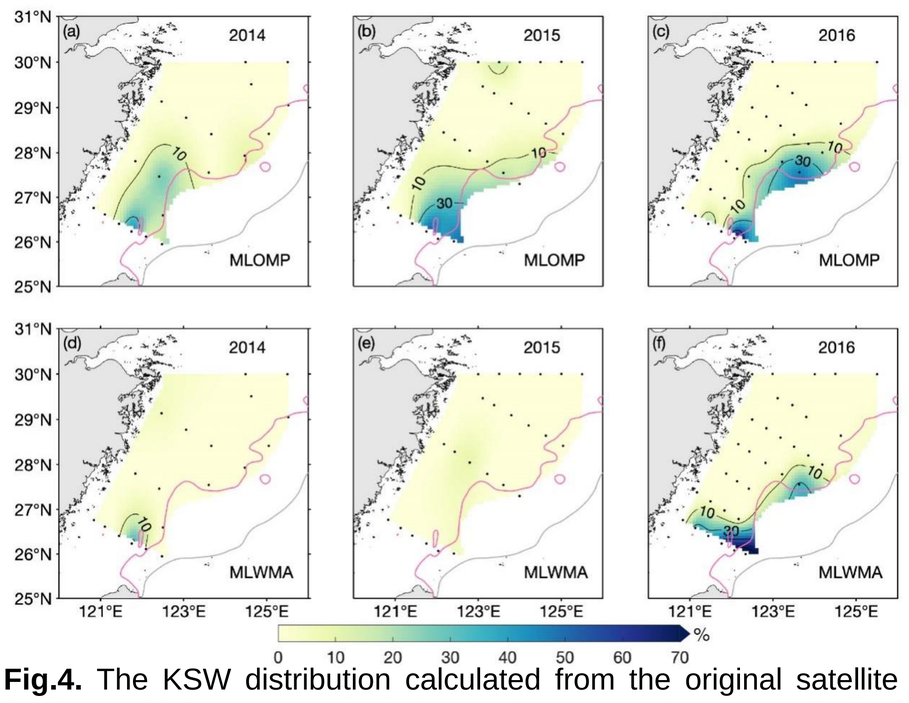

Fig.4. The KSW distribution calculated from the original satellite SST and SSS using MLOMP (a, b, c) and MLWMA (d, e, f). The pink and gray contours are the 100 m and 200 m isobaths respectively.

Surface water mass analysis using satellite data

- We examine the water mass analysis with the satellite SST and SSS as proxies of source water properties by MLOMP and MLWMA methods.
- When comparing with Figure 2, the temporal variation and spatial pattern of the KSW intrusion given by the MLOMP analysis are very similar but the quantity is overestimated for 2015 and underestimated for 2016.
- Overall, the MLWMA results based on the satellite and in-situ data are very alike. They well capture the year-to-year variations of the KSW intrusion in a qualitive way, and tend to underestimate the KSW proportion for all three years.

References

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