**Response to reviewer**

We would like to deeply thank the reviewer for constructive comments which greatly improve the manuscript. The followings are detailed response to each comment. Corresponding modifications are highlighted in the new submission.

To Reviewer 3 (Dr. Eitarou Oka),

*1. I understood the authors' story that less NPSTMW was formed in 2018-2021 compared to 2012-2015 due to less atmospheric cooling and the resultant smaller MLD. However, Figure 13a shows that negative temperature anomalies during 2012-2013 when the PDO index was negative as in 2018-2021. Isn't there a possibility that positive temperature anomalies during 2018-2021 are due to horizontal heat advection from the meandering Kuroshio south of Japan? Moreover, isn't this heat advection the major cause of the less formation of NPSTMW after 2018? This is the only major comment from me. Otherwise, the manuscript is relatively well written, and I recommend its publication in OS after the above issue is addressed.*

**Response**: We thank the reviewer's valuable comment and recommendation. Through the ML heat budget analysis, the average of temperature tendency anomaly during the cooling season of 2018-2021 (Figure 12b) is positive. It is contributed by the air-sea heat exchange (38.0%), the vertical entrainment through the base of the ML (37.0%), the Ekman advection (17.6%), and the geostrophic advection (7.4%). This result demonstrates that, in the NPSTMW formation region, the weak processes of the air-sea heat exchange and the vertical entrainment play an important role in the ML warming during 2018−2021. The weak temperature advection by the Ekman flow also makes contributions to the warming of local MLT. This result is demonstrated in section 3.4 of the new submission (L341-388).

In addition, although the KE is in a stable state in 2018-2021, the average of geostrophic advection anomaly is negative during 2018-2021, which does not tend to warm the wintertime MLT as in 2012-2015 (Figure 12b). Thus, we study the parts attributable to geostrophic advection anomaly (Eq.(R1), Figure R1). The geostrophic advection anomaly is contributed by $-\left(\overline{\mathbf{u}}_g \cdot \nabla T_m'\right)$ (36.4%), $-\left(\mathbf{u}_g' \cdot \nabla \overline{T}_m\right)$ (32.8%), and $-\left(\mathbf{u}_g' \cdot \nabla T_m'\right)$ (30.8%). Even though the advection of mean temperature by the anomalous geostrophic flow ($-\left(\mathbf{u}_g' \cdot \nabla \overline{T}_m\right)$) is positive (negative) in the stable (unstable) KE state during 2004-2021, which is also pointed out in Qiu (2000), the averaged advection of anomalous temperature by the mean geostrophic flow ($-\left(\overline{\mathbf{u}}_g \cdot \nabla T_m'\right)$) and $-\left(\mathbf{u}_g' \cdot \nabla T_m'\right)$ has largely negative effect on geostrophic advection anomaly during 2018-2021 (Figure R1). It indicates that the decreasing temperature gradient ($\nabla T_m'$) in the winter causes the recent cooling of the sea surface temperature in the ventilation region (Figure R1). Thus, we think that the positive temperature anomalies during 2018-2021 are not due to horizontal heat advection from the meandering Kuroshio south of Japan.

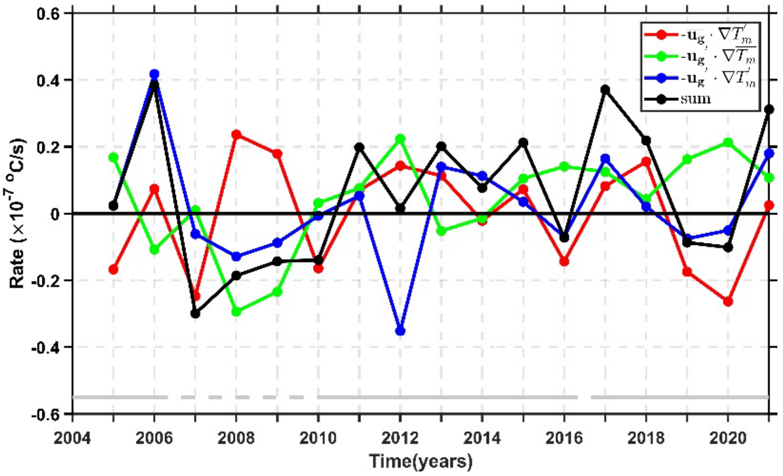


**Figure R1: Yearly time series of the anomaly of values (positive value indicates that the term increases MLT) contributes to the geostrophic advection anomaly (sum term in this Figure) relative to the 2004−2021 climatology from October of the previous year to March (cooling season) in Eq. (R1). Values are averaged in the wintertime ventilation region of 141°E−180°, 30°N−34°N. Solid (dashed) bars indicate stable (unstable) periods of the KE.**

According the method of Toniazzo et al. (2010), the geostrophic advection anomaly can be decomposed into the attributable parts:

$$-\left(\mathbf{u}_g \cdot \nabla T_m\right)' = -\overline{\mathbf{u}}_g \cdot \nabla T_m' - \mathbf{u}_g' \cdot \nabla \overline{T}_m - \mathbf{u}_g' \cdot \nabla T_m' \qquad \text{(R1)}$$

Here, Overbar denotes a climatological average. Prime represents the anomalous values relative to the climatological average.

Toniazzo, T., Mechoso, C. R., Shaffrey, L. C., and Slingo, J. M.: Upper-ocean heat budget and ocean eddy transport in the south-east Pacific in a high-resolution coupled model, Clim. Dyn., 35, 1309–1329, 2010.
Qiu, B.: Interannual variability of the Kuroshio Extension system and its impact on the wintertime SST field, J. Phys. Oceanogr., 30, 1486–1502, 2000.

*2. L33: south of the Kuroshio Extension (KE) -> south of the Kuroshio and the Kuroshio Extension (KE).*

**Response**: Thanks. Modified (L40).

*3. L70-72, "In recent years, KE is in a stable state associated with the Kuroshio large-meander (LM) path south of Japan (Figure 1). Although a persisting Kuroshio LM and the resultant stable state of the KE has already exceeded four years (Qiu and Chen, 2021; Usui, 2019), the NPSTMW volume has declined since 2018 (Oka et al., 2021)." I would expect more detailed explanation here for readers' understanding. I would write, "In August 2017, KE switched from an unstable state to a stable state in association with the occurrence of the Kuroshio large-meander (LM) path south of Japan (Figure 1), although negative SSH and MTD anomalies associated with the positive PDO phase were arriving from the central North Pacific (Qiu et al. 2020, JC). Since then, Kuroshio LM and the stable state of the KE have lasted for more than six years (Qiu and Chen, 2021; Qiu et al., 2023; Usui, 2019), while the NPSTMW volume has declined (Oka et al., 2021)." Note that the current stable KE state seems to have begun with the initiation of LM (Qiu et al., 2020), it has also been supported by basin-wide wind forcing (Qiu et al., 2023, GRL).*

**Response**: Thanks. Modified following reviewer's suggestion (L77-82).

*4. L95, "net surface heat flux (HF)": This notation is somewhat misleading in eq. (5) (L158) because it looks like a product of H and F. Consider using a single character.*

**Response**: Thanks. Modified as $Q_{\mathrm{net}}$ (L118， L171).

*5. L108, "sigma-theta = 25.0-25.5 kg m-3": To what temperature range does this density range correspond? I am just curious if the warmest (lightest) variety of NPSTMW formed south of Japan, especially in the Kuroshio LM period (Nishikawa et al., 2023, JO), is included in the authors' analysis.*

**Response**: This density range in our study corresponds to the temperature range as 16-18 ºC, which is mainly formed in the wintertime ventilation region of 141°E−180°, 30°N−34°N. These are the relatively cold NPSTMW. Thus, the warmest (lightest) variety of NPSTMW (exceeding 19 °C) formed south of Japan, especially in the Kuroshio LM period (Nishikawa et al., 2023, JO), is not included in our analysis.

*6. L169-170, "Except for a short time of 2006-2009 when the KE jet is unstable, the NPSTMW volume has a dramatic decrease during 2006-2009.": I do not understand. Do the authors mean, "In a short time period of 2006-2009 when the KE jet is unstable, the NPSTMW volume has a dramatic decrease."?*

**Response**: Yes, thanks. Modified （L211-212）.

*7. L221-223, "transformation rates ... were greatly reduced.": Not obvious for me from Fig. 7a,c.*

**Response**: Thanks. The Figure 7 and discussion of this figure have been modified (L274-287).

*8. L223-225, "the annually averaged surface formation rates ... density range": Not obvious for me from Fig. 7b,d.*

**Response**: Thanks. The Figure 7 and discussion of this figure have been modified (L274-287).

*9. L273, "Except for the KE dynamic state change,": I do not understand. Maybe, "In addition to the KE dynamic state change,", although the KE dynamic state and "oceanic precondition" are not independent from each other.*

**Response**: Yes, thanks. Modified (L390-391).

*10. L311, "is leaded": "is led"?*

**Response**: Thanks. Modified (L445).