Supplementary information:

1. **Spectral method:** According to Torres et al. (2018), the kinetic energy (KE) spectral density can be decomposed into divergent (DIV) contribution and rotational (RV) contribution. The relationship between KE, DIV and RV in the spectral space is given by: $\widehat{KE} = |\widehat{RV}|^2/k^2 + |\widehat{DIV}|^2/k^2$, where k is wave number, $\widehat{}$ represents the Fourier transform, $||$ stands for the spectral density. The balance processes are no-divergence, then DIV contribution mainly comes from the unbalance motions. Since tidal effects are not included in ROMS, the unbalance internal waves are negligible. We assume that the unbalance motions mainly refer to submesoscale motions. When the ratio of DIV and RV contribution to KE is close to 0.1, the contribution of the DIV part is non-negligible, implying the role of submesoscale motions (Cao et al., 2021). The variation of the ratio in different times and wave number is shown in Fig. S1. The estimated scale is 16 km, which is close to 15 km.
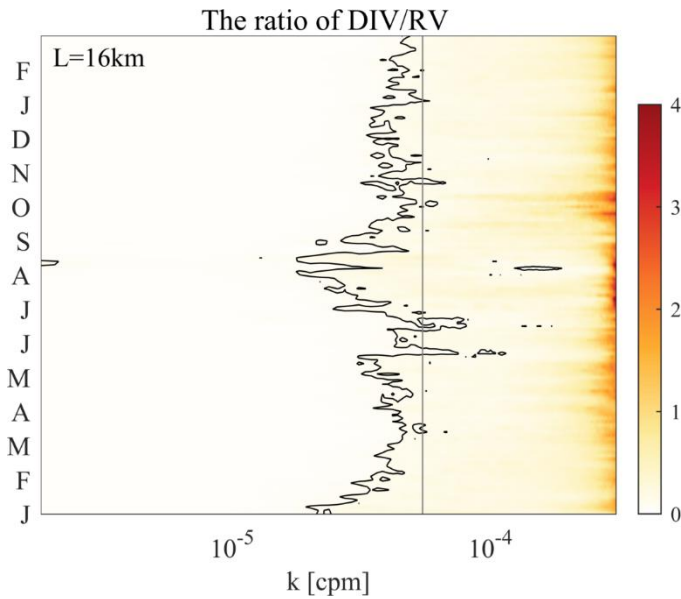
Fig. S1. The ratio (color) of DIV and RV contribution to KE spectrum varies with wave number. The black contours represent the ratio equal to 0.1. The gray line represents the average wavelength corresponding to 0.1 isocline over the entire period.

2. The spatial distribution of density at surface in different seasons (spring and winter).

a. 29th April

b. 29th December
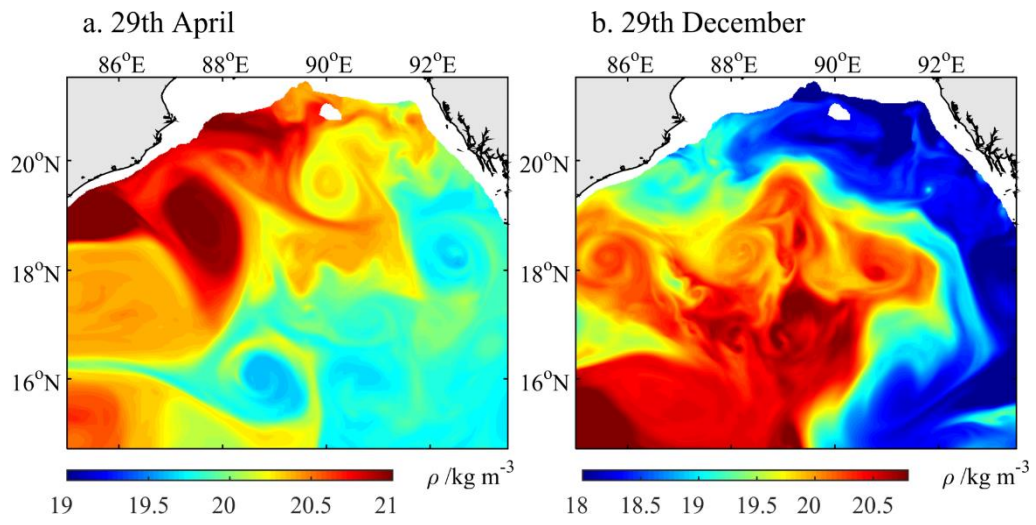
Fig. S2. The snapshot of density at surface in 29 April (a), 29 December (b).