Vertical mixing and inertial motions by high frequency wind variability in the stratified Yellow Sea during summer

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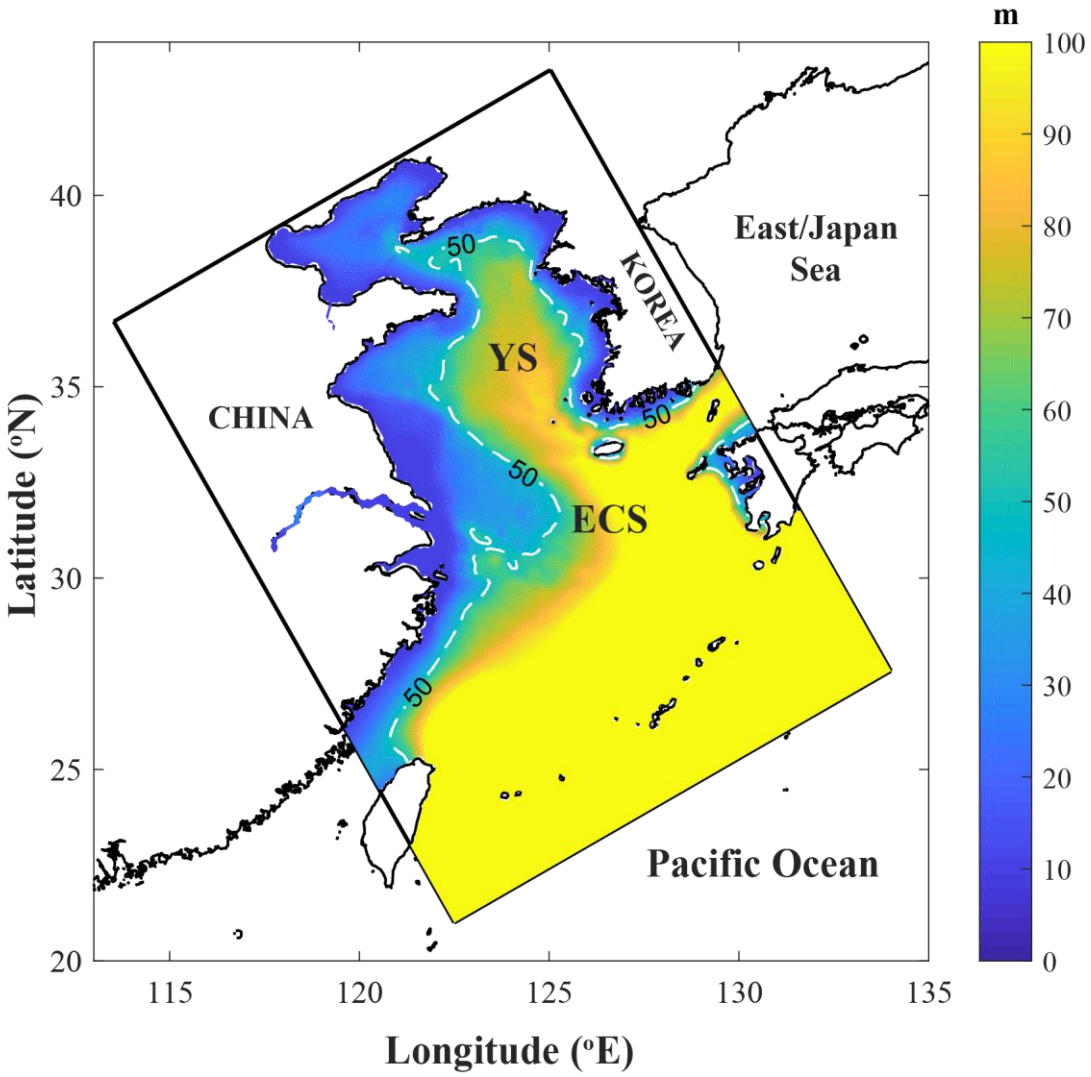
Introduction

Objectives

To examine the impact of **the time intervals of wind forcing** on the surface heat flux, mixed layer temperature (MLT), and mixed layer salinity (MLS) in a shelf sea circulation model

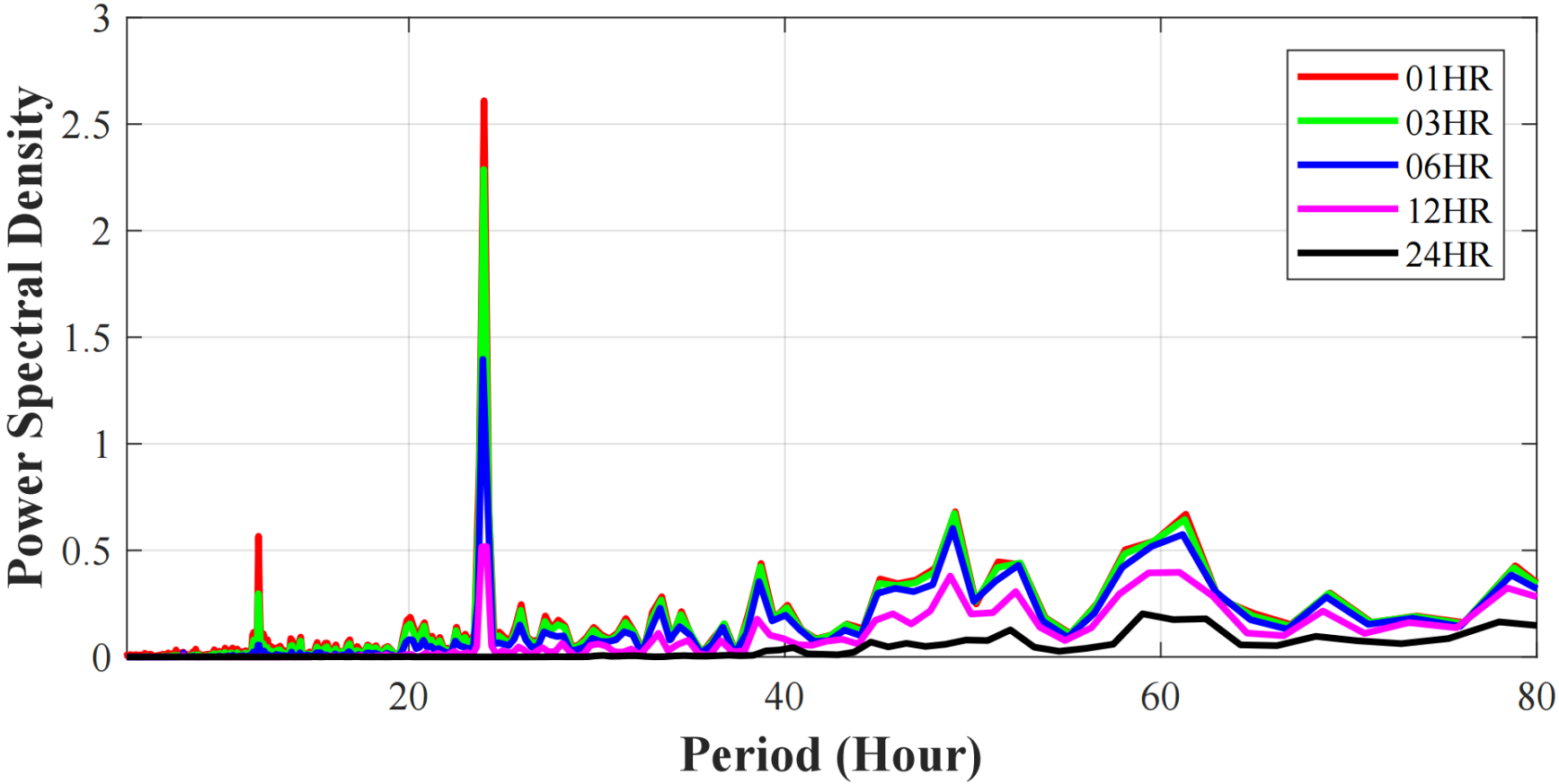
To identify the physical processes that drive changes in the characteristics of surface mixed layer. The physical processes causing the changes were investigated by calculating quantitatively the contribution of each term in the **heat budget equation** for the surface layer and by analyzing the **energy spectrum** of temperature and current variations.

Introduction



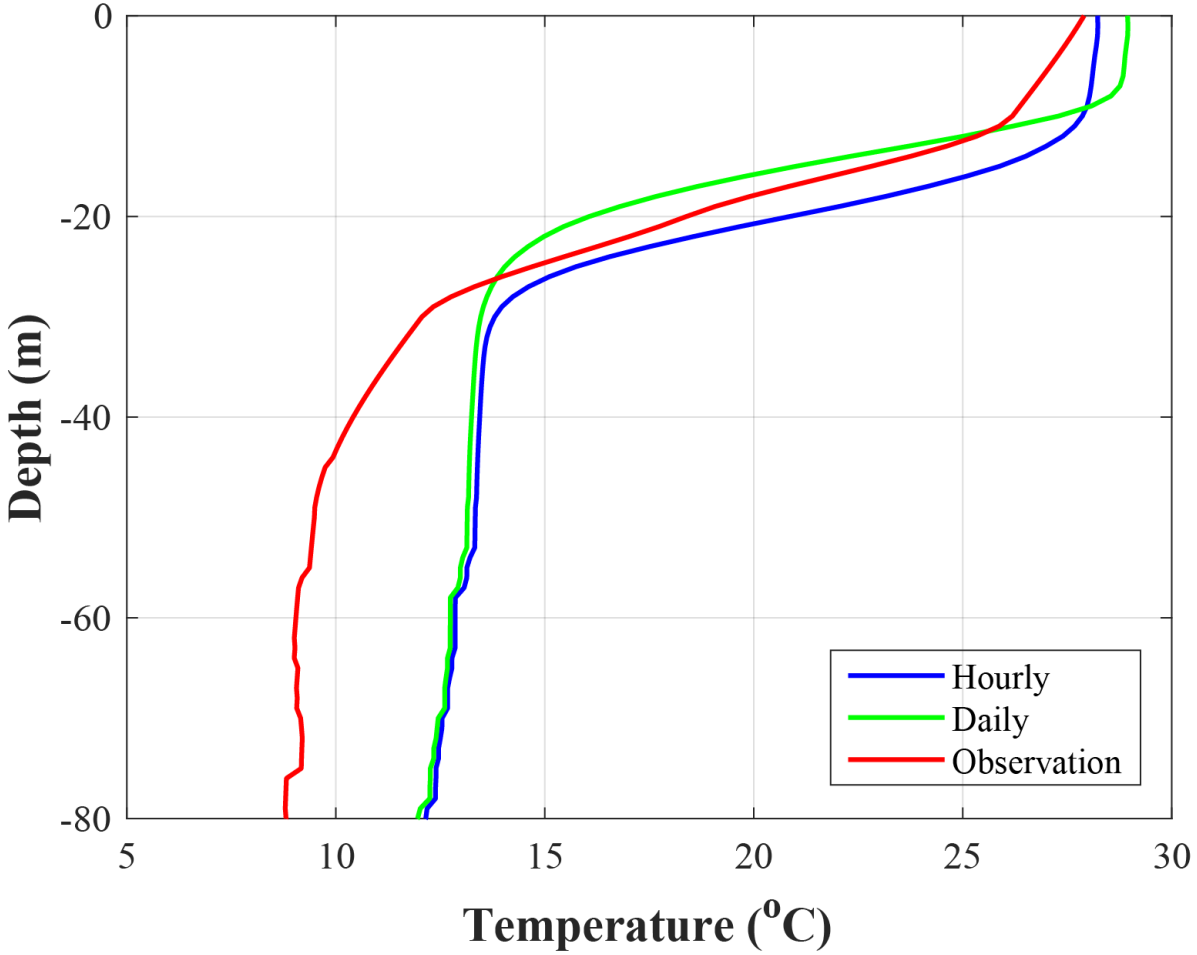
Model domain and bottom topography in the **Yellow Sea (YS)** and East China Sea (ECS). Color indicates bottom depths in meter and white dashed contour represents 50 m isobath.

Introduction



Power spectral density of wind speed variations at the Maldo station from **1, 3, 6, 12, and 24-hour interval data** from the WRF model from June to August 2010.

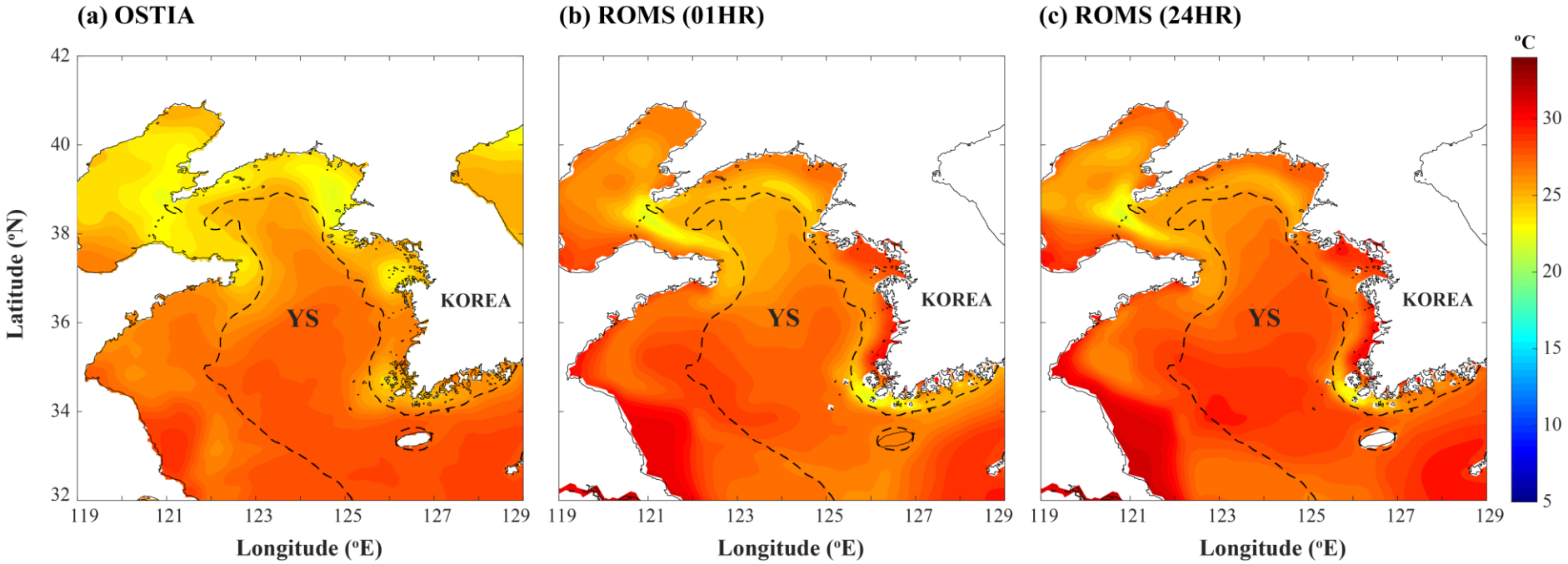
Results



MLD is defined as the depth of h at which the density (ρ) increases 0.125 kg m^{-3} from the surface value:
$\rho(h) = \rho(0) + 0.125$ kg m^{-3}.

Comparison of **vertical average temperature profile** at the bi-monthly observation stations along line 307 to line 312 of NIFS in the deep (> 50 m) southeastern Yellow Sea during August 2010.

Results

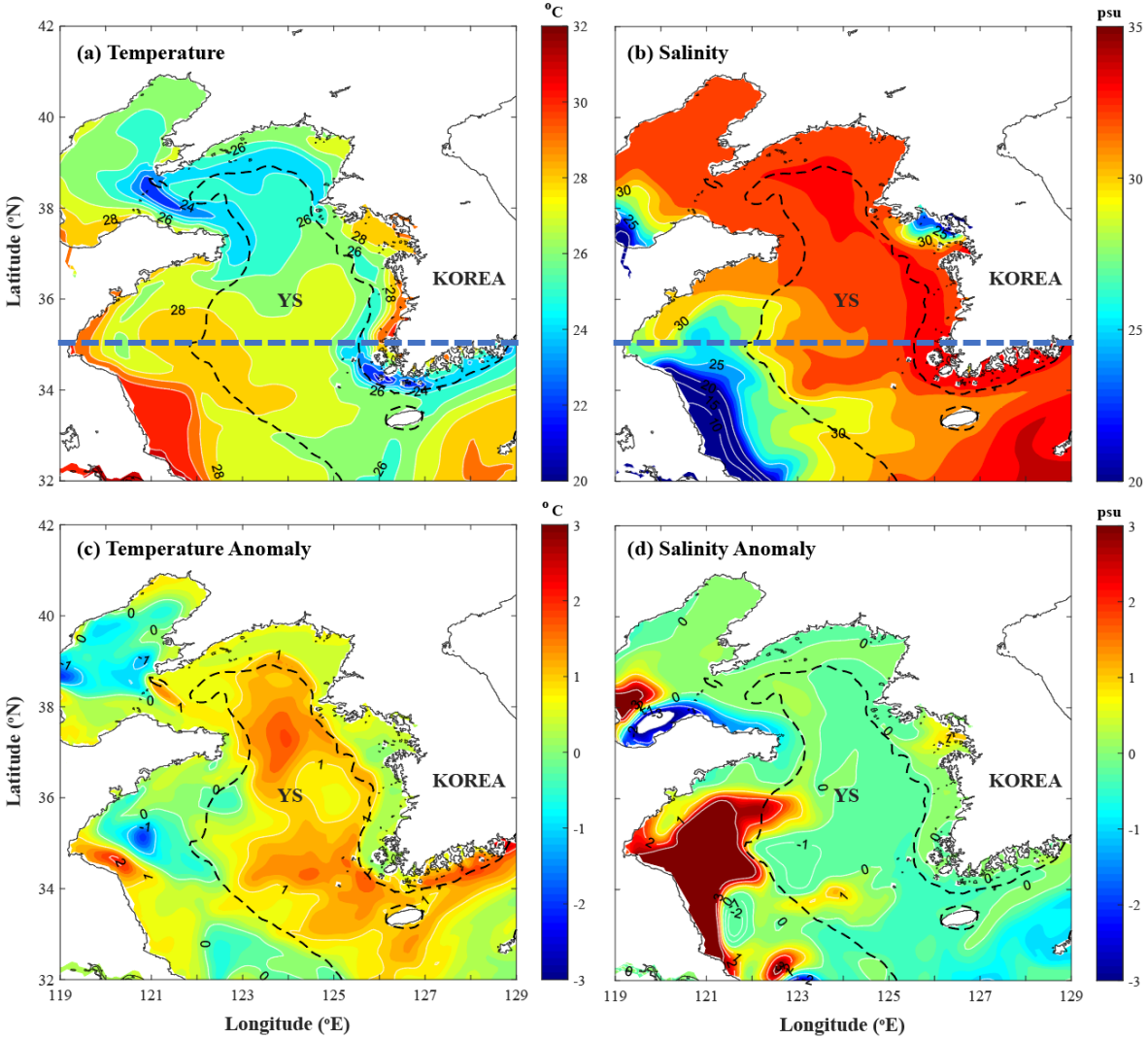


Comparison of **monthly mean sea surface temperature** from (a) OSTIA and (b) hourly and (c) daily wind forcing simulations **in August** 2010. Black dashed line represents 50 m isobath. YS represents the Yellow Sea.

Results

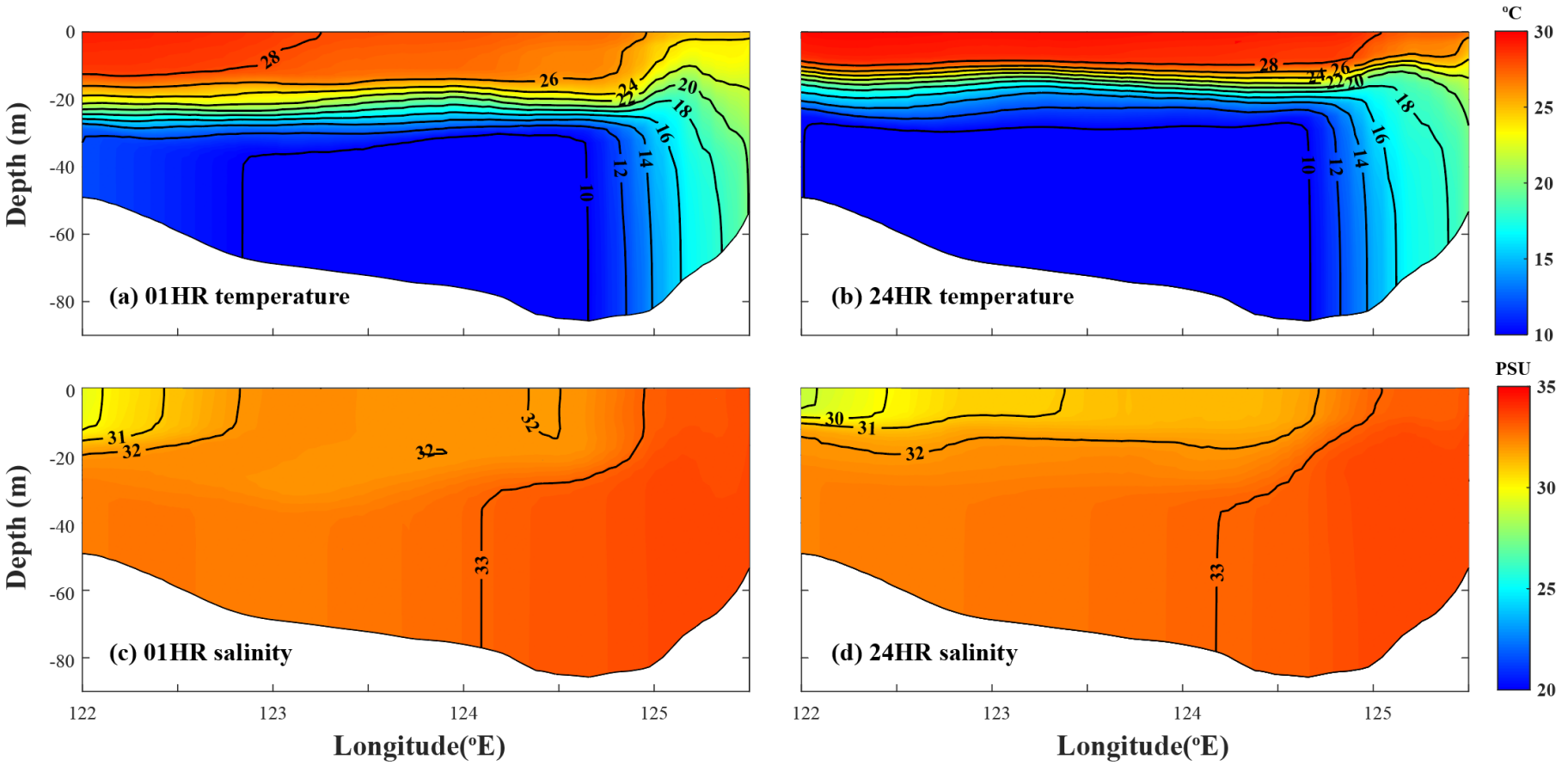
hourly wind

deviation by daily wind



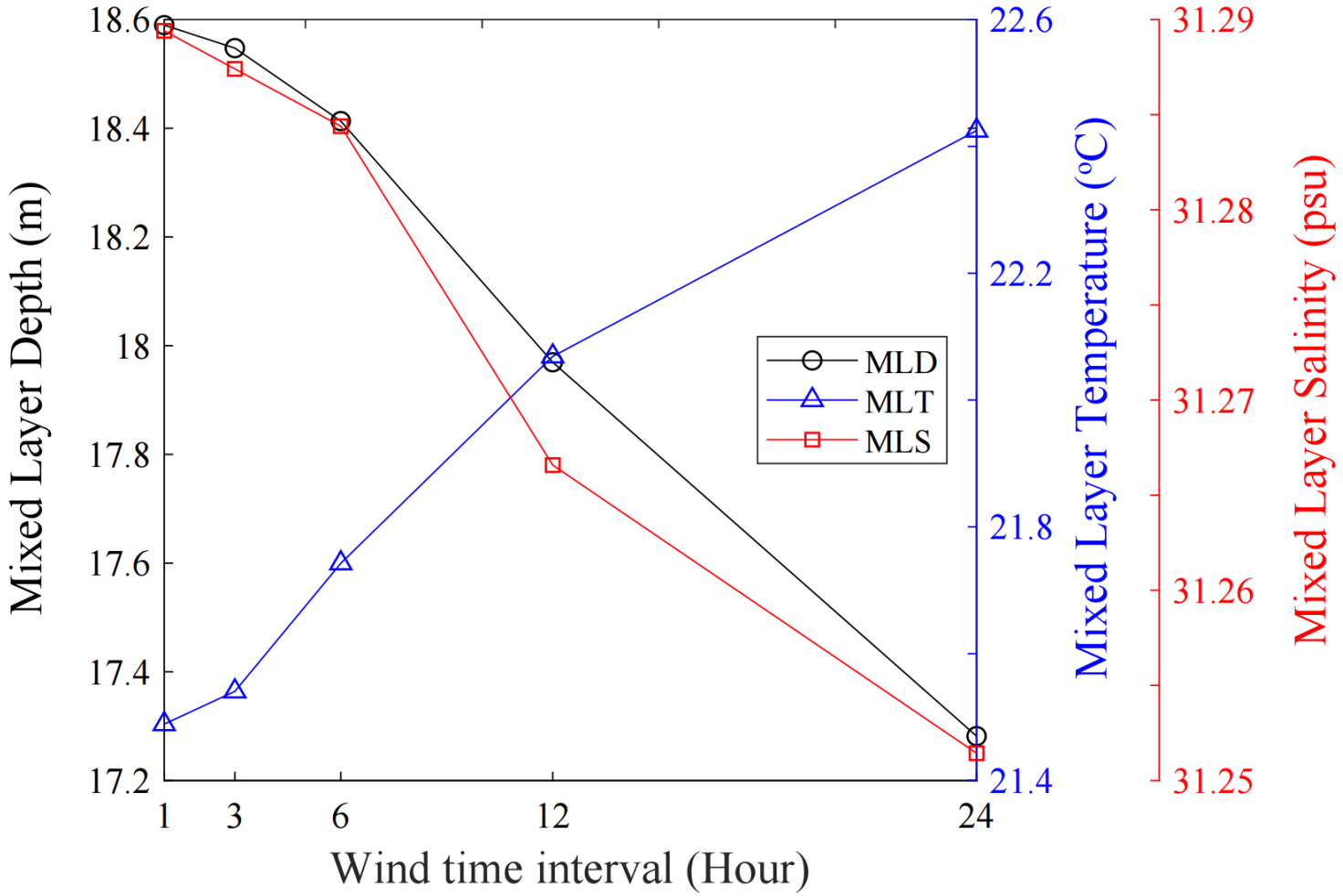
Distribution of the surface mixed layer (a) **temperature** and (b) **salinity** in **August** 2010 from the **hourly wind forcing** simulation. Deviation of the surface mixed layer (c) temperature and (d) salinity in the **daily wind forcing** simulation relative to those in the hourly wind forcing simulation in August 2010. Black dashed line represents 50 m isobath. YS represents the Yellow Sea.

Results



Vertical sections of **temperature** and **salinity** in (a, c) hourly and (b, d) daily wind forcing simulations along the 35°N on August 11, 2010.

Results



Mean **mixed layer depth** (MLD), **temperature** (MLT), and **salinity** (MLS) in the simulations with four intervals of wind forcing **from May to September** 2010 in the deep central Yellow Sea (bottom depth > 50 m). MLD is defined as the depth at which the density (ρ) increases 0.125 kg m^{-3} from the surface value.

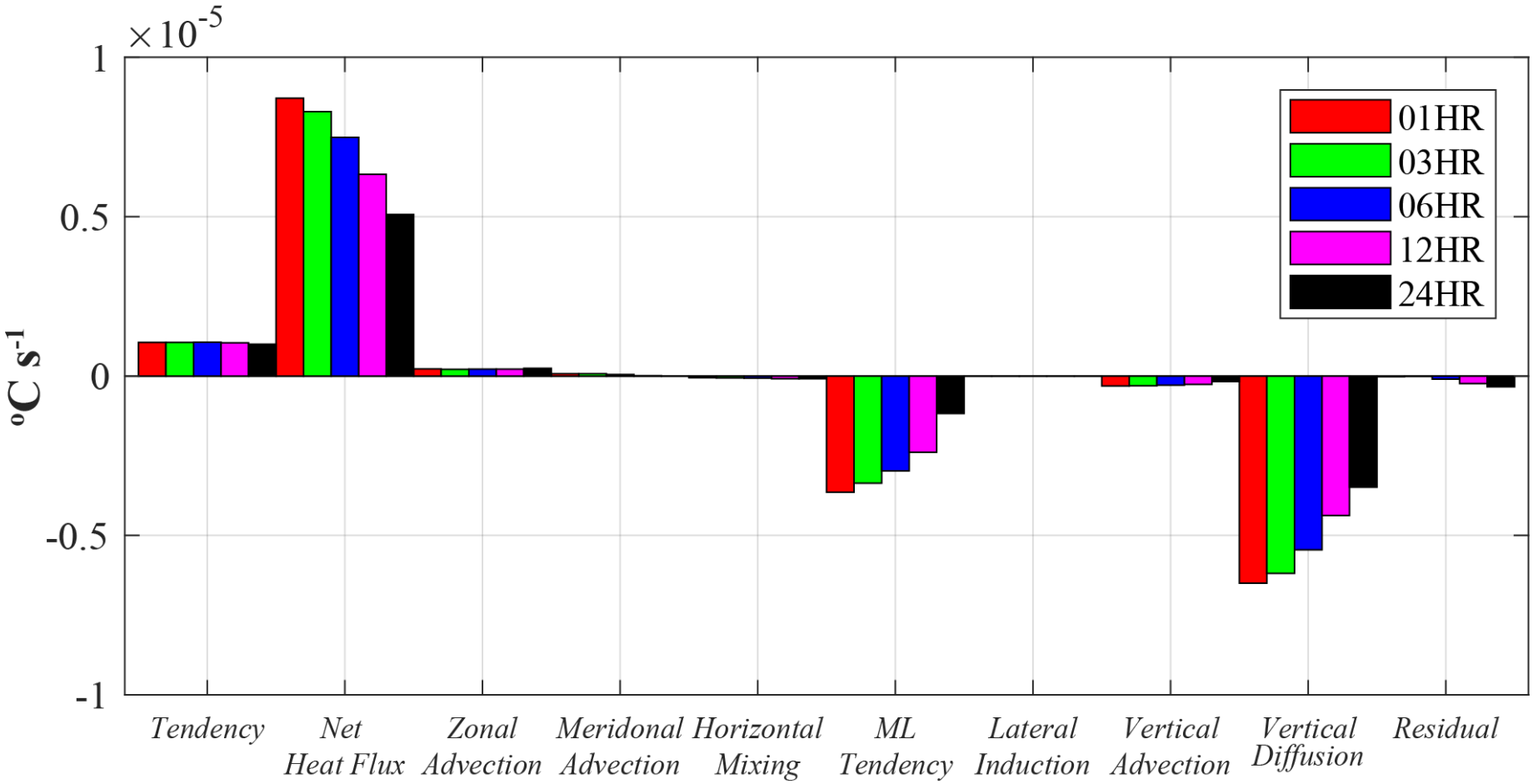
Heat budget in the **surface mixed layer**

$$\underbrace{\frac{\partial T_a}{\partial T}}_{Tendency} = \underbrace{-\left(u_a \frac{\partial T_a}{\partial x} + v_a \frac{\partial T_a}{\partial y}\right)}_{Horizontal\ advection} + \underbrace{\kappa_H \left(\frac{\partial^2 T_a}{\partial x^2} + \frac{\partial^2 T_a}{\partial y^2}\right)}_{Horizontal\ diffusion} - \underbrace{\frac{1}{h}\left[\kappa_Z \frac{\partial T}{\partial z}\right]_{-h}}_{Vertical\ diffusion}$$

$$- \underbrace{\left(\frac{T_a - T_{-h}}{h}\right)\left(\underbrace{\frac{\partial h}{\partial t}}_{ML\ tendency} + \underbrace{u_{-h}\frac{\partial h}{\partial x} + v_{-h}\frac{\partial h}{\partial y}}_{Lateral\ induction} + \underbrace{w_{-h}}_{Vertical\ advection}\right)}_{Entrainment} + \underbrace{\frac{q_0 - q_{pen}}{\rho_0 c_p h}}_{Net\ heat\ flux}$$

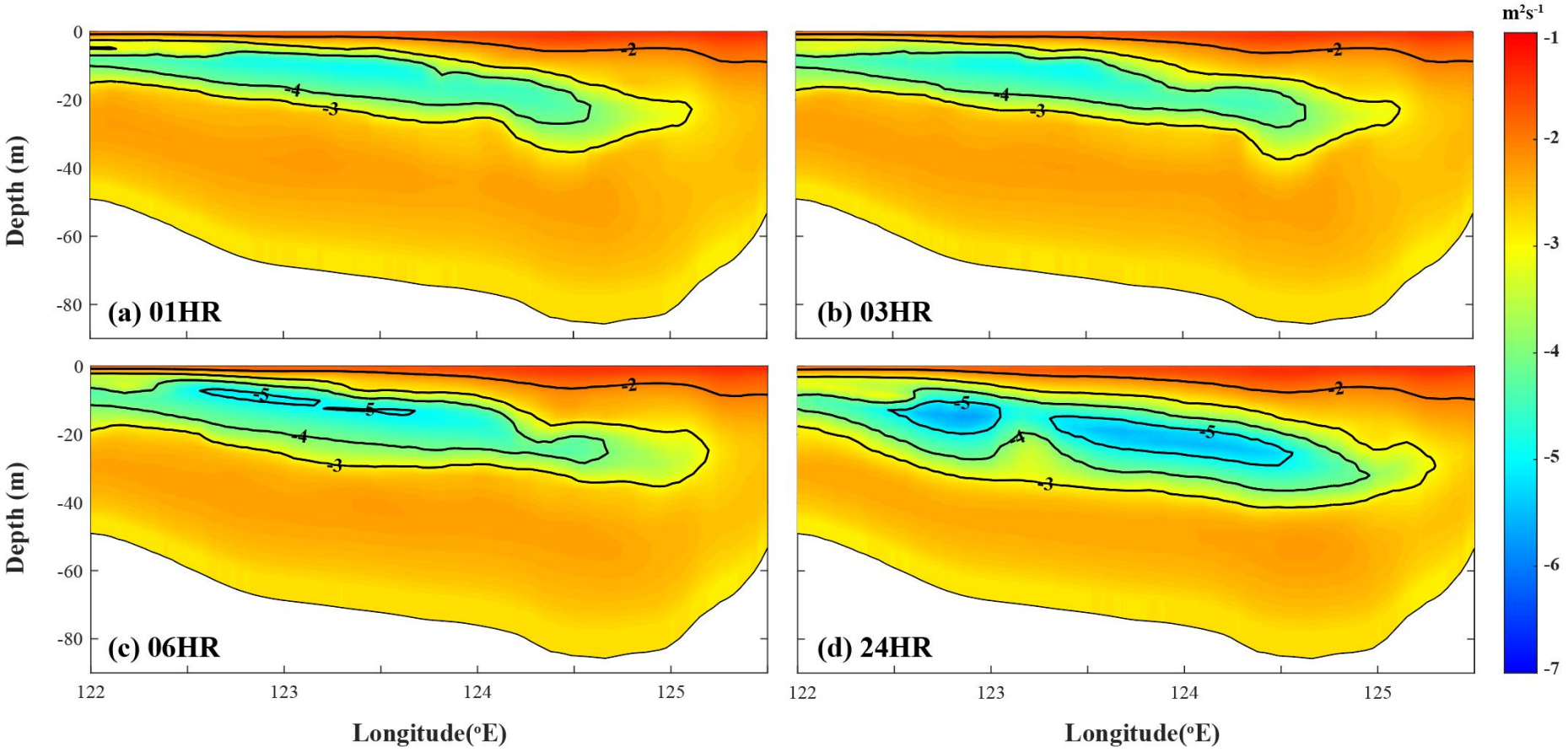
T is temperature, ρ_0 is mean density of sea water in the ML, h is MLD, c_p is specific heat capacity of sea water, and u and v are horizontal eastward and northward components of velocity, respectively. The subscript a represents the vertical average value in the mixed layer, and subscript $-h$ indicates the value at the mixed layer base.

Results



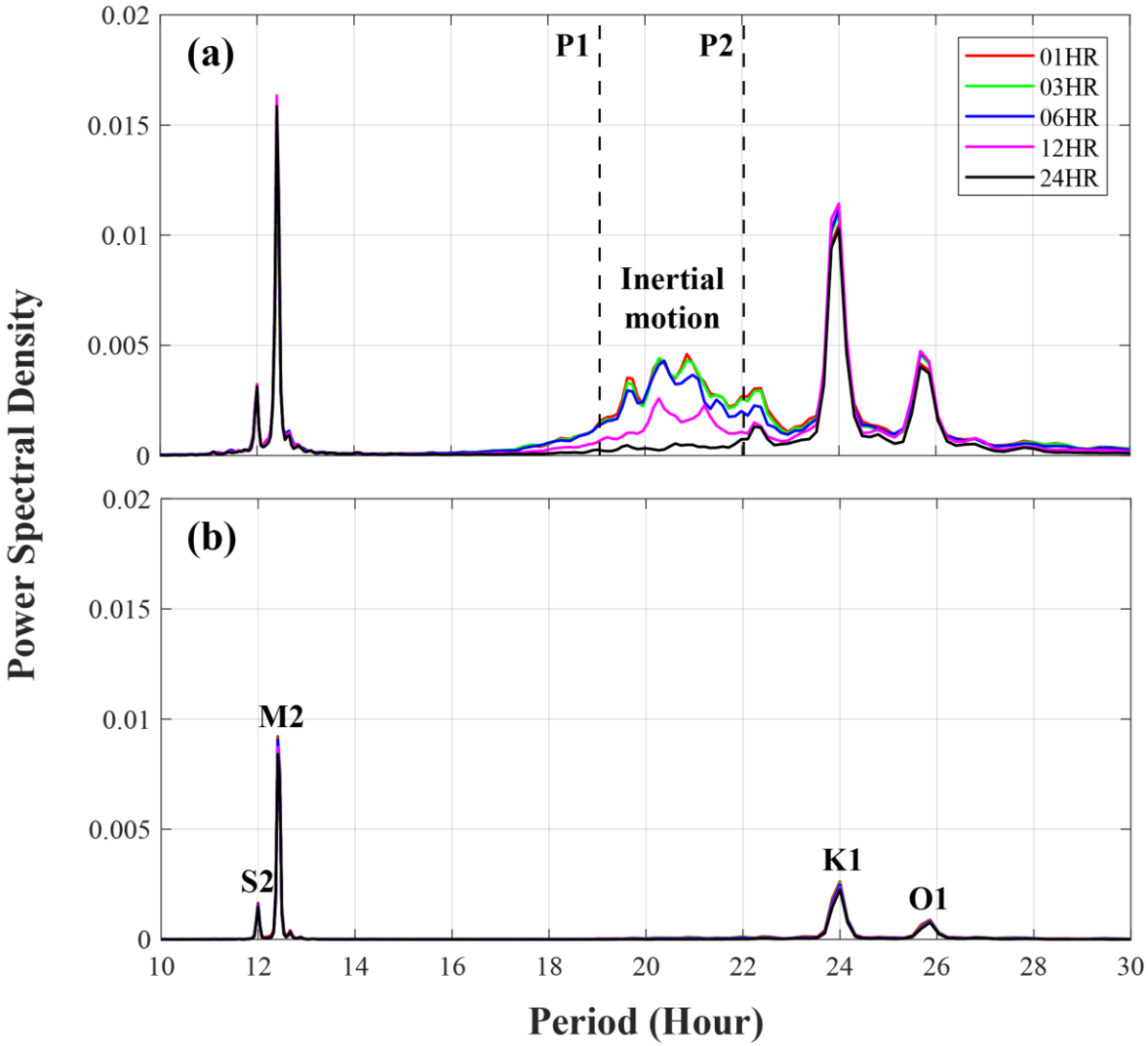
Contribution of **physical processes** (terms in heat-budget equation) on the tendency of the **surface MLT** in the central Yellow Sea from May to September.

Results



Vertical section of mean **eddy diffusion coefficient, log(Kz),** along the 35°N transect from May to September.

Results

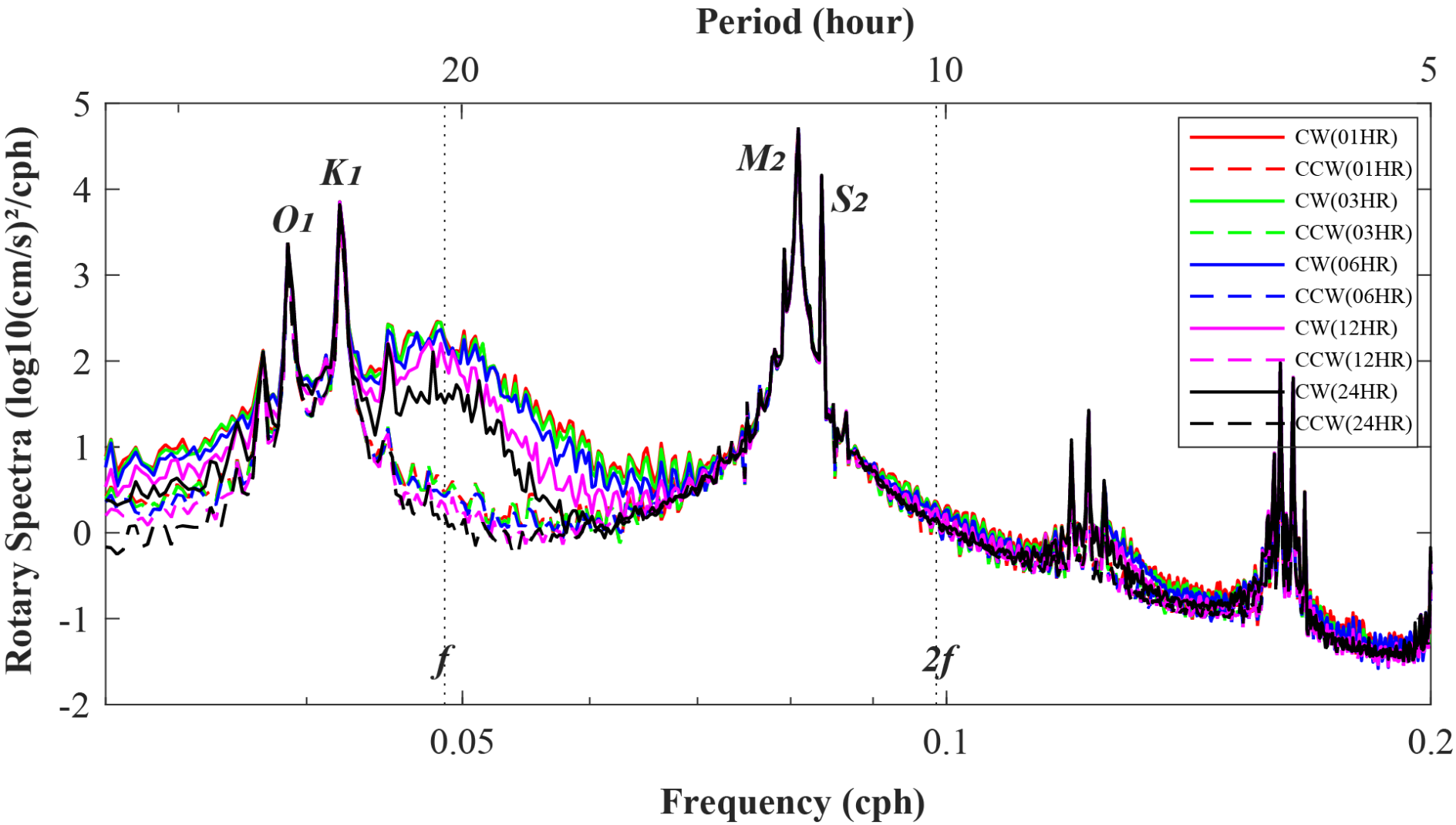


Upper Layer

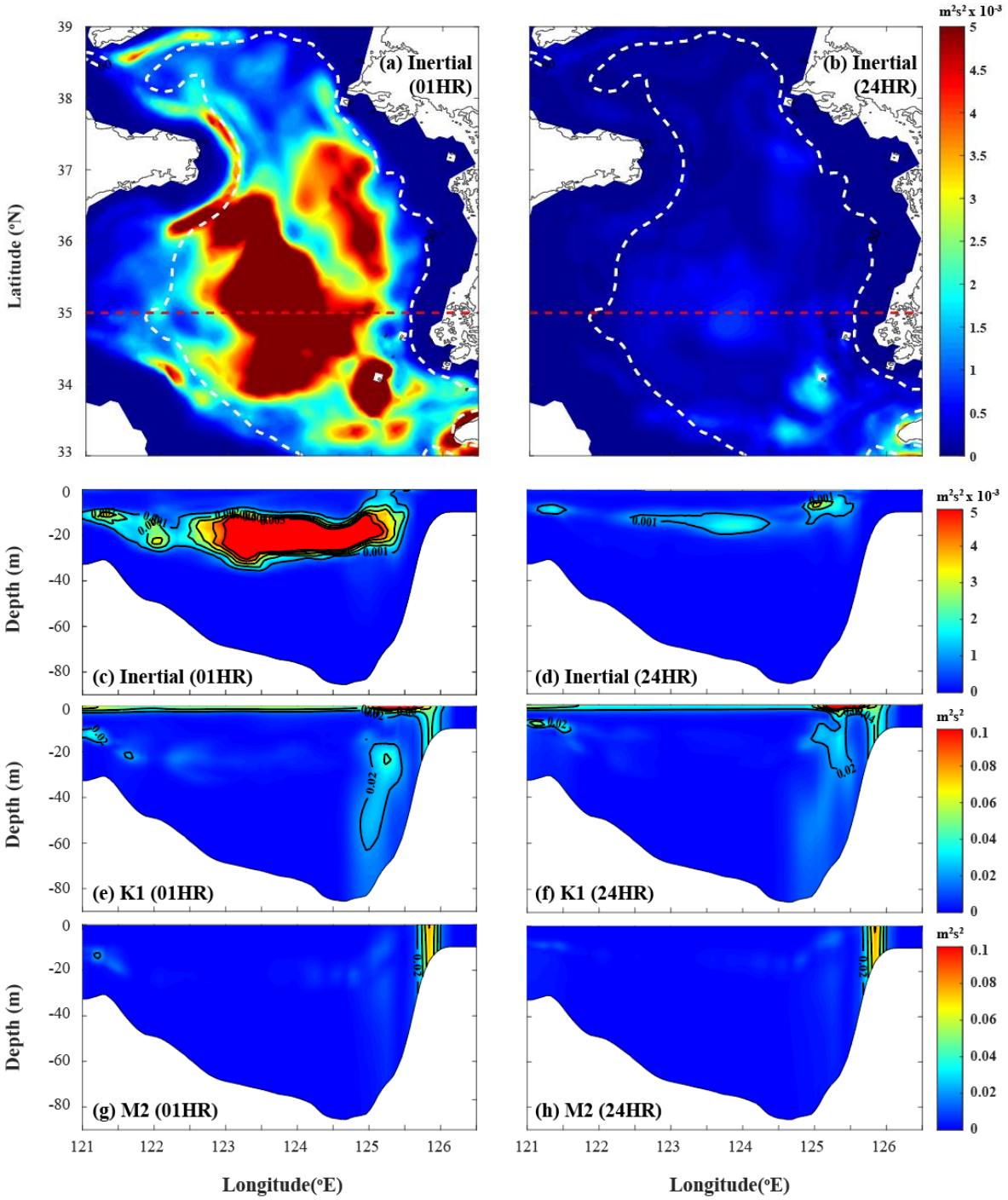
Lower Layer

Power spectral density of **temperature variations** in (a) the upper and (b) lower layers of the deep central Yellow Sea, where the bottom depth is deeper than 50 m. Inertial period ranges from 19.06 hour (P1) to 22.03 hour (P2) in the central Yellow Sea.

Results



Rotary spectra of **current vectors** at a depth of 15 m in the deep central Yellow Sea, where the bottom depth is deeper than 50 m. CW and CCW represent clockwise and counterclockwise components,



Power spectral density of **temperature variations** from the (left panels) hourly and (right panels) daily wind interval simulations. (a, b) Horizontal distribution of mean power spectral density in the **inertial periods** from the depths of 10–30 m.

Vertical distribution of power spectral density in (c, d) the **inertial motion**, (e, f) **K1** tidal, and (g, h) **M2** tidal periods along the 35°N section.

Summary

To identify physical processes that affect the characteristics of surface mixed layer (ML) in the Yellow Sea, and to determine the necessary time interval of wind forcing that generates the responsible physical process, numerical simulations were performed with wind forcing time intervals of **1, 3, 6**, 12, and 24 hours.

As the temporal resolution of wind forcing increased, the **net surface heat flux into the surface layer was raised** and the activity of **near-interval waves** and **vertical mixing** were enhanced in the upper thermocline layer.

The vertical mixing process by the near-inertial waves increased the surface mixed layer depth and salinity and decreased the mixed layer temperature.

At least a **6-hourly interval of wind forcing** was required to reproduce saturated energy density in **inertial oscillations** and **vertical mixing** in the thermocline layer of the stratified Yellow Sea.

Thank you for your attention!

Any questions or comments