Influence of warm surface water originating from the East China Sea on surface water temperature off the south coast of Korea in summer

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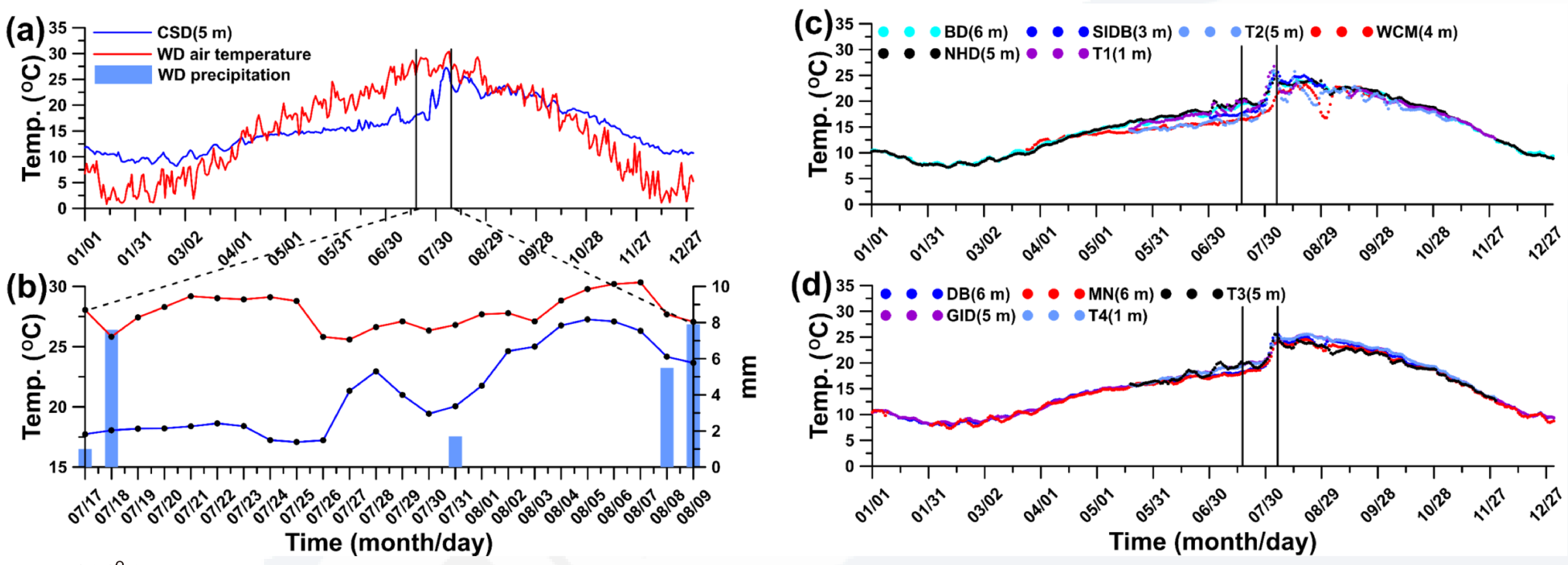
1. Motivation and objective



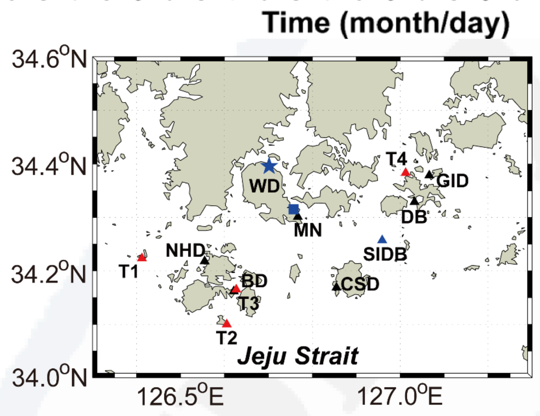


Fig. 1. Temporal variations in water temperature at Cheongsando (CSD, blue solid line) and air temperature (red solid line) and precipitation (light blue bar) at Wando (WD): (a) in 2017 and (b) from July 17 to August 9, 2017. (c, d) Time series of the daily mean surface temperature at 11 coastal surface temperature observation stations in 2017. Surface temperature datasets were observed and provided by Chonnam national university (JNU), National Institute of Fisheries Science (NIFS) and Korea Hydrographic and Oceanographic Agency (KHOA). Atmospheric datasets were also provided by Korea Meteorological Administration (KMA)

Table 1. Water temperature measured at observation stations on July 25 and August 4, 2017. The two highest temperature difference are shown in the green box.

Station		BD	NHD	T1	T2	CSD	SIDB	DB	MN	T3	GID	T4	WCM
Temperature (°C)	July 25	18.9	19.4	18.7	16.5	17.0	17.9	18.7	18.5	19.1	20.0	19.9	16.8
	August 4	25.3	24.3	26.8	26.0	26.8	25.0	25.6	23.9	25.5	23.7	24.3	20.1
	Difference	6.4	4.9	8.1	9.5	9.8	7.1	6.9	5.4	6.4	3.7	4.4	3.3

- **In the southwestern coastal region of Korea, abrupt surface temperature rise occurred in summer 2017. Especially, temperature rise more than 9°C was observed by the temperature data logger in the offshore (T2 and CSD) of the southwestern region (Kim et al, 2022).**
- **The objective of this study is to identify the cause of abrupt surface water temperature rise (i.e. warm water event) in the southwestern coastal region of Korea using an ocean circulation model.**

2. Model configuration and validation

- **Regional Ocean Modeling System (ROMS)**
  - **Horizontal grid spacing: 1/100°**
  - **Vertical grid: 41 σ layers**
  - **Bathymetry: Korbathy30s dataset**
  - **Open boundary condition: 1/12° Mercator Ocean global reanalysis model**
  - **Atmospheric forcing: ERA-interim reanalysis dataset**
  - **Tidal forcing: TPXO6 (M_2, S_2, N_2, K_2, K_1, O_1, P_1, M_f, M_m)**

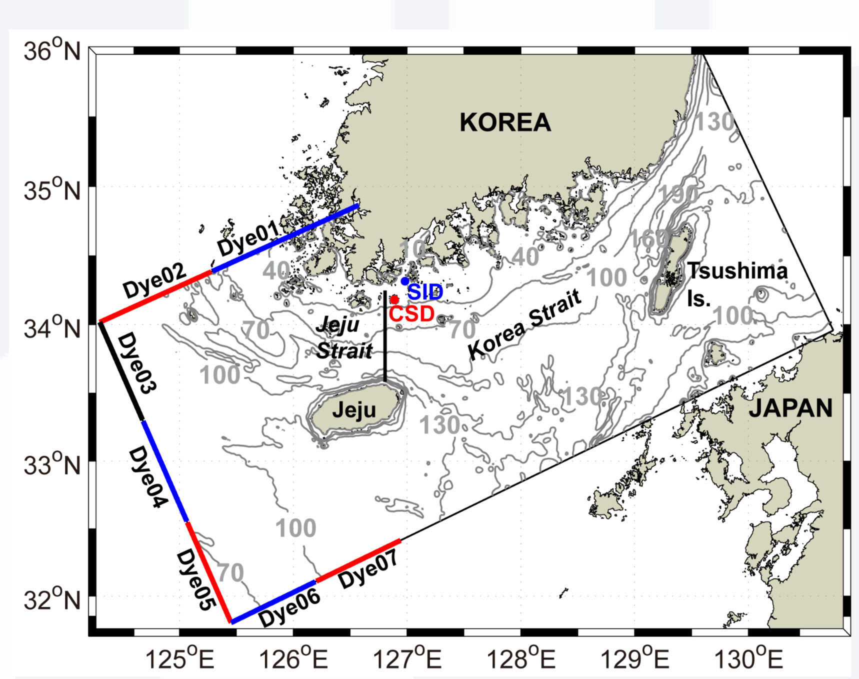


Fig. 2. Model domain and bathymetry (gray contours). Passive tracers (dye) were released at the open boundary from segments Dye01 to Dye07. Red blue dots indicate CSD and Saengildo (SID), respectively. The vertical sections presented in this study are along the black solid line across the Jeju Strait.

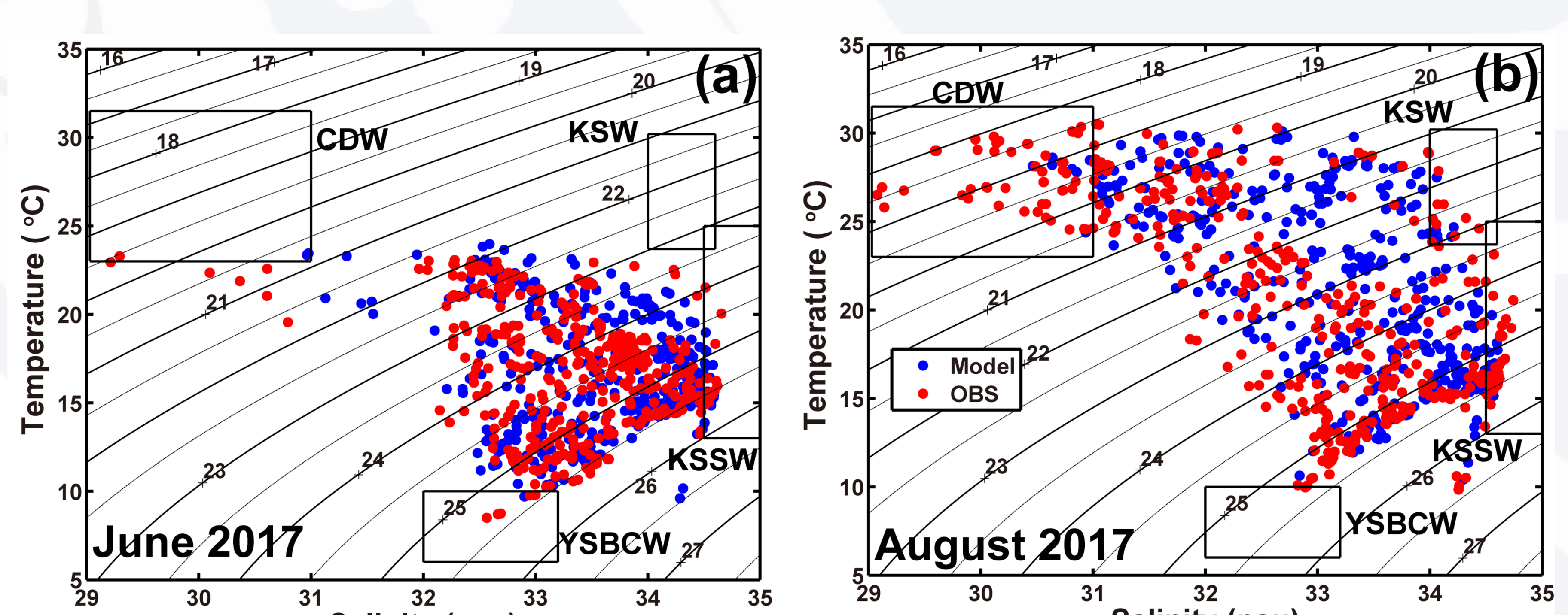


Fig. 3. Comparison between simulated and observed (NIFS survey) hydrographic data in the East China Sea and Korea Strait using T-S diagram in (a) June and (b) August 2017. Red and blue dots represent the observed and simulated water types, respectively. The CDW, KSW, KSSW and YSBCW indicate the Changjiang Diluted Water (Kim et al., 2020), Kuroshio Surface Water, Kuroshio Subsurface Water (Qi et al., 2014) and Yellow Sea Bottom Cold Water (Hur et al., 1999), respectively.

- **Although the distribution of simulated water types showed little difference compared to the observed water types, the overall distribution patterns of temperature and salinity on the T-S diagram were similar between simulation and observation in both June and August (Fig. 3).**

Reference

Hur, H.B., Jacobs, G.A., and Teague, W.J., 1999. Monthly variations of water masses in the Yellow and East China Seas, November 6, 1998. J. Oceanogr. 55, 171-184.

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Kim, S.H., Choi, B.K., Kim, E., 2020. Study on the behavior of the water temperature inversion layer in the northern East China Sea. J. Mar. Sci. Eng. 8(3), 157.

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3. Results and conclusion

3.1. Abrupt surface temperature rise by the easterly wind

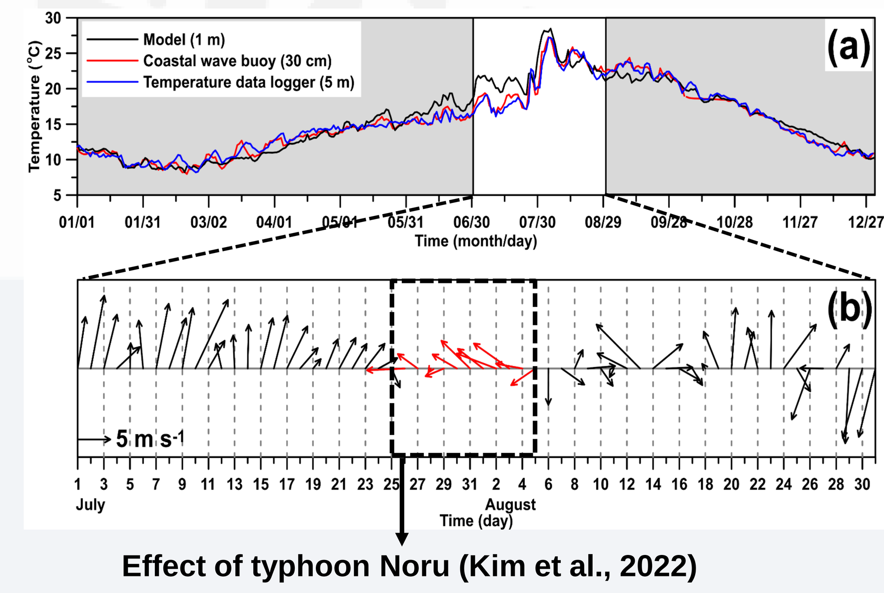

Fig. 4. Time series of (a) the daily mean sea surface temperature from model (black line), KMA buoy (red line), and NIFS data logger (blue line) at CSD and (b) the spatial mean ECMWF wind vectors in the southwestern region of Korea (124-128°E, 33-35°N) from July 1 to August 31, 2017. Red vectors represent the easterly winds during the abrupt surface temperature rise event.

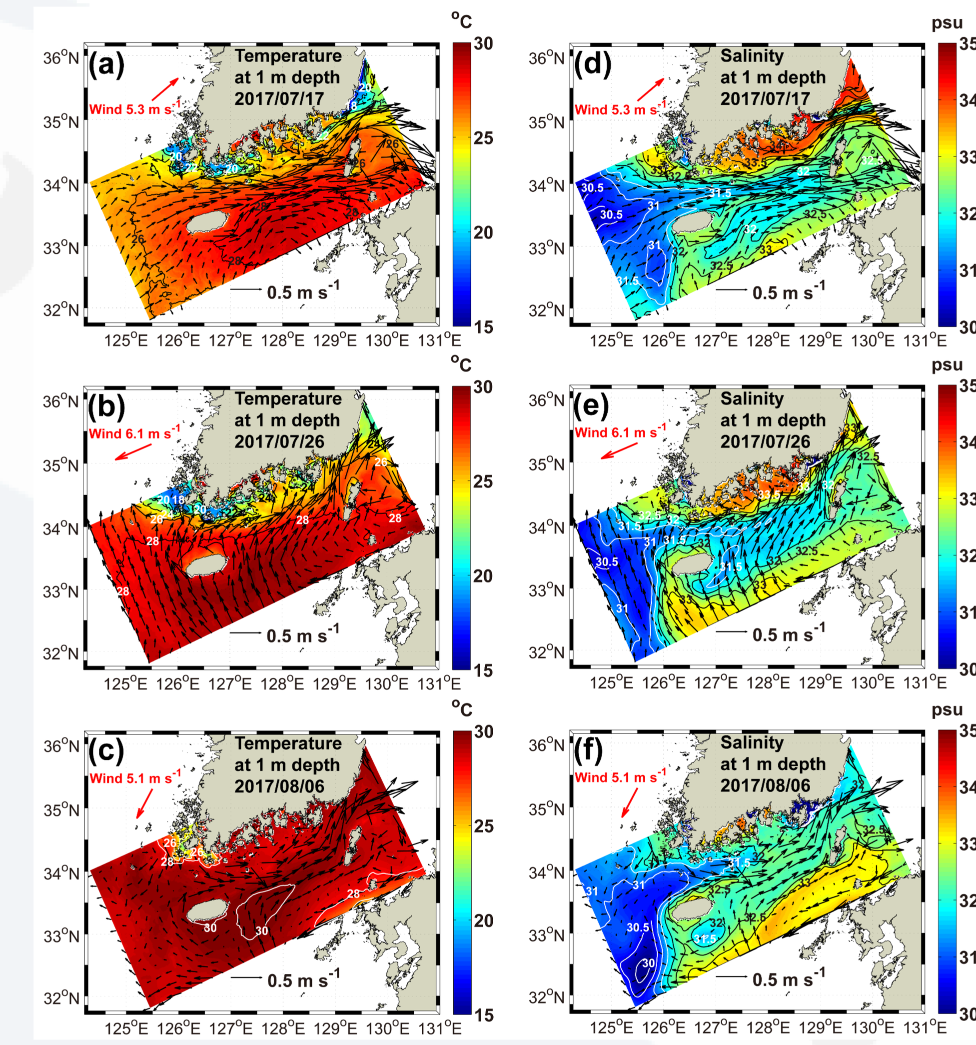

Fig. 5. Horizontal distribution of the simulated surface temperature (upper panel) and salinity (bottom panel) with current vectors on (a and d) July 17, (b and e) July 26, and (c and f) August 6, 2017. The red vectors represent the spatial mean ECMWF wind in the model domain.

- **When the easterly wind blew, abrupt temperature rise appeared in the simulated and observed time-varying temperature (Fig. 4).**
- **When the southwesterly wind blew, eastward surface currents dominated and surface temperature and salinity in the southwestern shallow region of Korea were cooler and saltier compared to the Jeju Strait on July 17 (Fig. 5 a and d).**
- **When the northeasterly wind blew, surface flows changed to the northward currents, surface temperature and salinity became warmer and fresher in the southwestern shallow region of Korea on August 6 through July 26 (Fig. 5 b, c, e and f).**

3.2. Passive tracer experiment

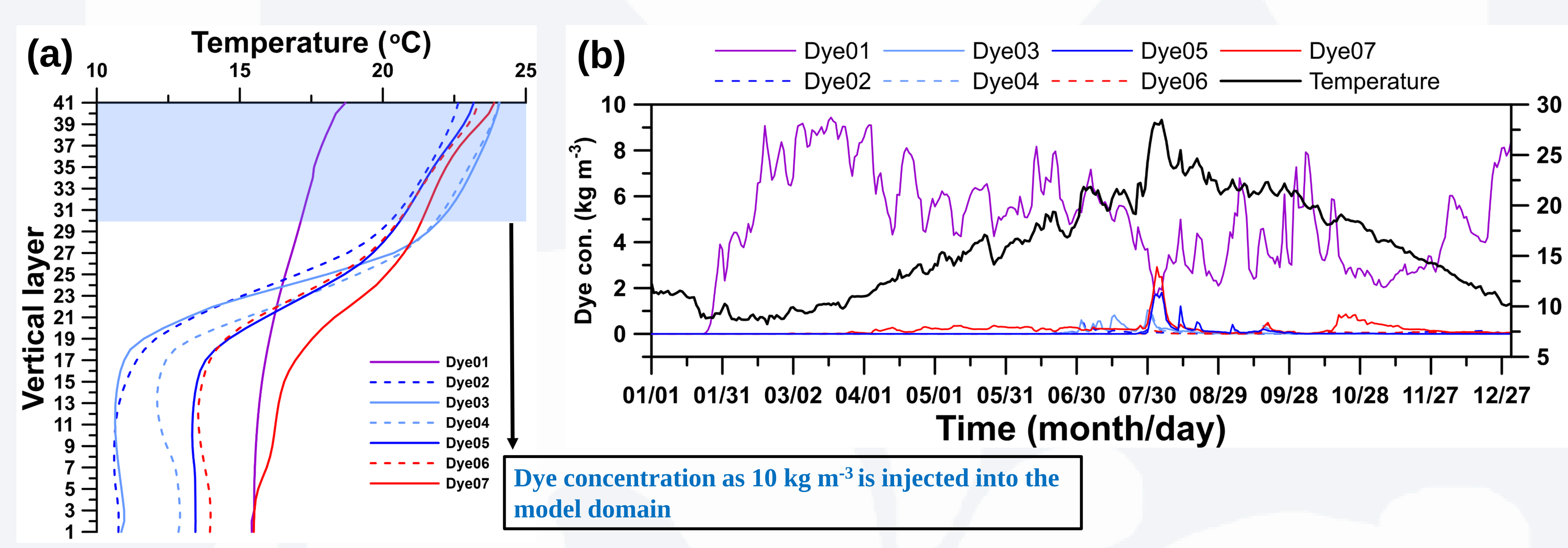

Fig. 6. (a) Vertical profiles of the spatial and temporal mean temperature in each dye release region in Fig.2. The light blue area from layer 30 to 41 indicates the vertical dye release layer in the model for all dye release regions except Dye01, where the entire vertical column was used. (b) Time series of dye concentrations and temperature at a depth of 1 m at CSD.

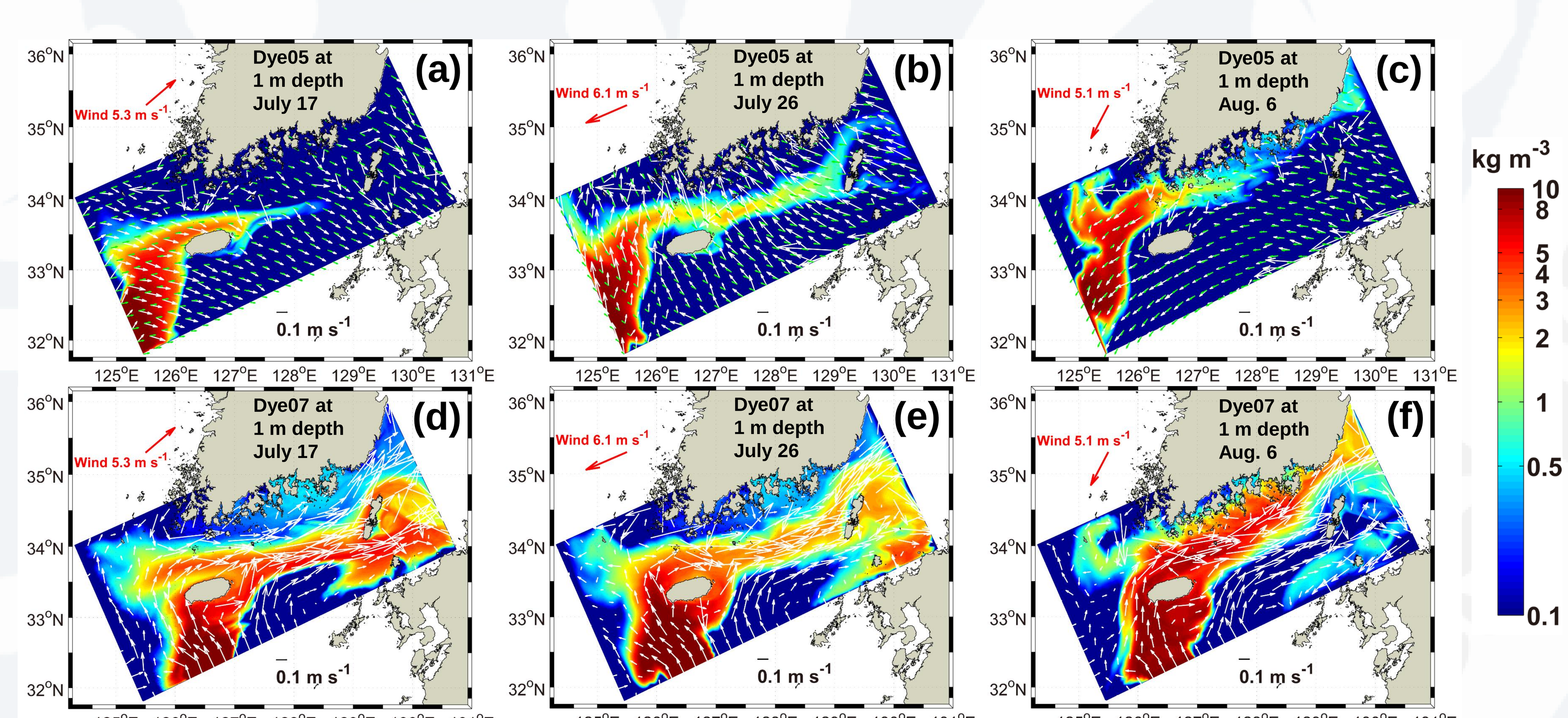

Fig. 7. Horizontal distribution of Dye05 (upper panel) and Dye07 (bottom panel) concentrations with ageostrophic (white vectors in the upper panels), theoretical Ekman (green vectors in the upper panels), and geostrophic (white vectors in the bottom panels) currents at a depth of 1 m on (a and d) July 17, (b and e) July 26, and (c and f) August 6. The red vectors are equal to those in Fig. 5. The colorbar of dye concentration is in log scale.

- **Dye05 and Dye07 were advected by the geostrophic currents from the East China Sea to the Korea Strait through the Jeju Strait (Fig. 7 d-f).**
- **During the abrupt surface temperature rise event, Dye05 and Dye07 (i.e. surface warm and less saline water in Fig. 5) were transported by the northward ageostrophic currents from the Jeju Strait to the southwestern coastal region of Korea (Fig. 7b and c).**
- **As a result, abrupt surface water temperature rise in the southwestern coastal region of Korea occurred through the northward Ekman transport of warm and less-saline water originated from the East China Sea in the Jeju Strait.**