Analysis of the Contribution of Water Temperature to Horizontal Density Distribution in the Gyeonggi Bay, Incheon Estuary Region

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Introduction

- In Gyeonggi Bay, seawater circulation is significantly influenced by the horizontal density gradient due to tide and freshwater discharge
- However, the correlation between water temperature and density increased ($R^2 > 0.85$) in the spring season at Gyeonggi Bay
- Therefore, this study aimed to determine the contribution of water temperature to density distribution in estuary

Study area

- Gyeonggi Bay (GGB)
  - ✓ Large tidal flats, macro tidal environment (7.9 m ~ 3.5 m)
  - ✓ Freshwater discharge is dominate in summer

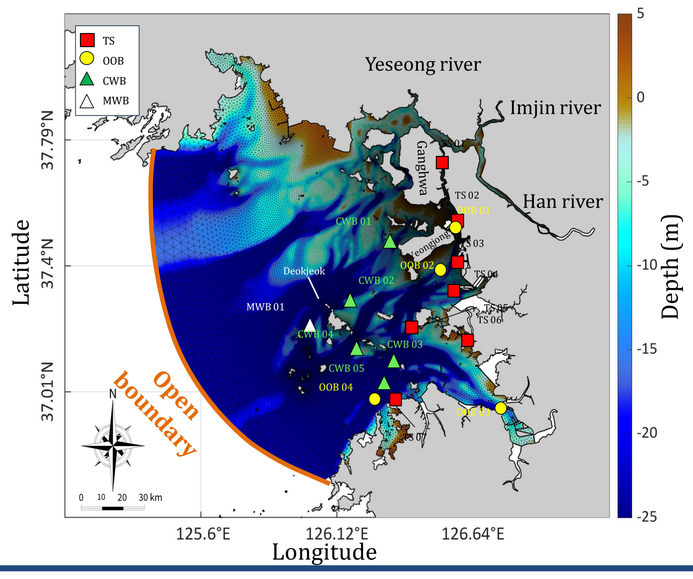
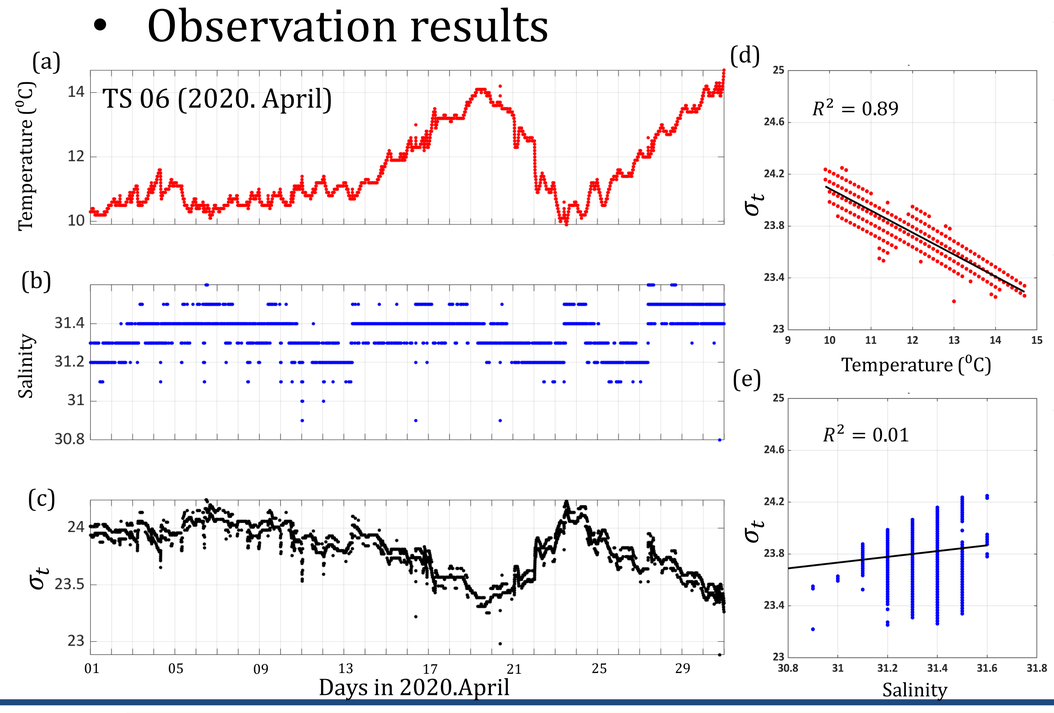


Figure 1. The study area and model domain: The Gyeonggi Bay (GGB) in the middle of west coast of Korea Peninsula. The model domain of GGB and locations of observation station are shown. Red squares are the Tide Stations(TS) operated by the Korea Hydrographic and Oceanographic Agency (KHOA). Yellow circles are location of Ocean Observation Buoy (OOB) operated by KHOA. Green triangles are Ocean Data Buoy (ODB)and Coastal Wave Buoy (CWB) which produce water temperature data operated by Korea Meteorological Administration (KMA).

- Observation results



- ✓ Density gradient is major factor determining residual flow
- ✓ Density (σ_t)is determined by water temperature (T), salinity (S) and pressure (p) $\sigma_t = \rho(T, S, 0) - 1000\ [kg/m^3]$
- ✓ Correlation between water temperature and density increase when there is a small salinity variance
- ✓ In spring season, water temperature also need to be considered to analysis residual flow in GGB

Figure 2. The time series of (a) water temperature, (b) salinity, and (c) density (σ_t) at TS 06 in April 2020. Right panels show Linear relation between (d) σ_t and temperature which coefficient of determination (R^2) is 0.89 and linear relation between (e) σ_t and salinity which R^2 is 0.01.

Methodology

- Model
  - ✓ Finite Volume Community Ocean Model (FVCOM)
  - ✓ Apply surface heat flux to FVCOM-GGB model used by Lee et al.(2021).

Model domain	
Resolution	100 m ~ 4,500 m, 20 vertical layers (fig. 1)
Depth	4.24 m ~ 102.28 m, (mean depth: 12.15 m) Korea Hydrographic and Oceanographic Agency (KHOA)
Model forcing	
Open boundary elevation	TPXO9-atlas (M_2, S_2, K_1, O_1, and N_2)
Open boundary temperature & salinity	HYbrid Coordinate Ocean Model (HYCOM)
River discharge & freshwater temperature	WAter resource Management Information System (WAMIS)
Water temperature initial condition	Daily sea surface temperature (SST) composite data (KHOA)
Surface heat flux	Fifth generation European Centre for Medium-Range Weather Forecasts Reanalysis data (ERA5)

- Validation

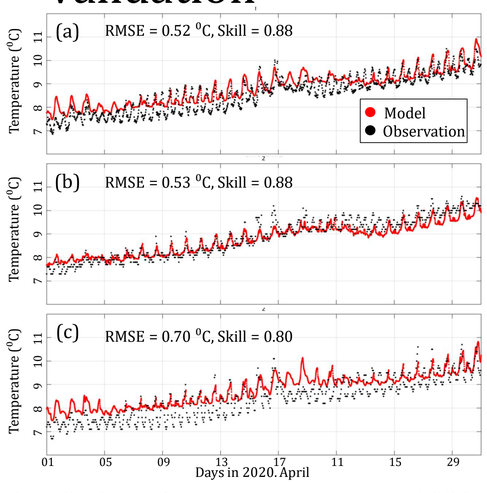


Figure 3. Time series of water temperature at (a) OOB 04, (b) CWB 02, and (c) CWB 05. Red is model result and black is observation data.

- ✓ $RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)^2}$
- ✓ $Skill = 1 - \frac{\sum_{i=1}^{N}(M_i - O_i)^2}{\sum_{i=1}^{N}(|M_i - \bar{O}| + |O_i - \bar{O}|)^2}$

$(M: model\ data, O: observation, data\ N: number\ of\ data)$

- ✓ Predicted skill (Skill) of elevation is calculated over 0.99 in all tidal station (TS 01 ~ TS 07)(Figure 1)
- ✓ Skill of salinity is calculated over 0.87 in winter and over 0.98 in summer (Lee et al., 2021)
- ✓ Skill range of water temperature is 0.55 to 0.89
- ✓ Relatively low accuracy of water temperature near large tidal flat

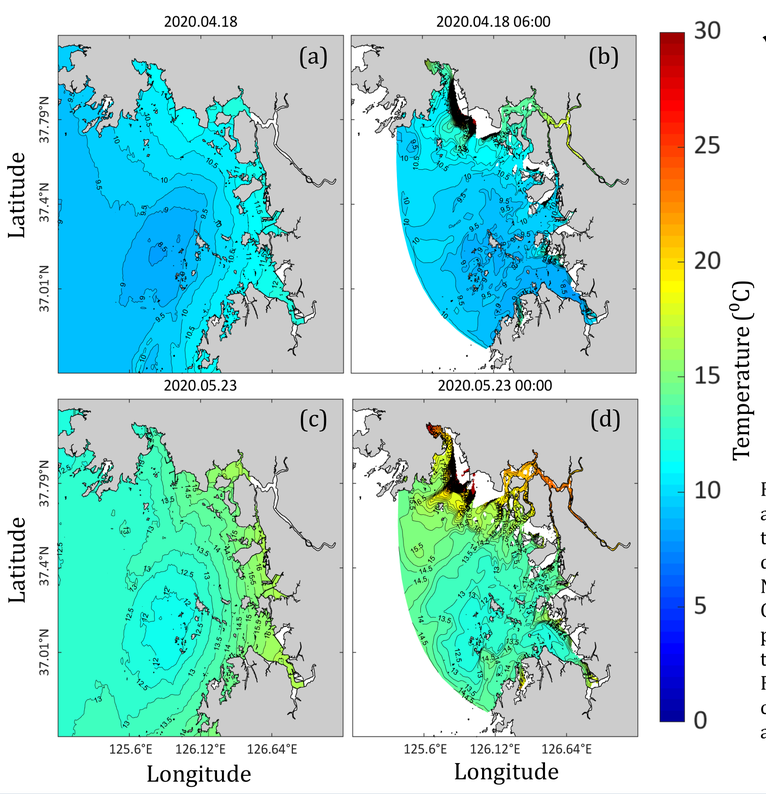


Figure 4. The right panels (a and c) are sea surface temperature (SST) synthesis data provided by the National Ocean Satellite Center of KHOA. The left panels (b and d) are water temperatures calculated by FVCOM. (a) and (b) is SST contour at April 17, 2020, (c) and (d) are SST at May 23.

- ✓ Similar SST distribution of SST composite data and FVCOM SST result (Figure 4)

Results and discussion

- Distributions of salinity, water temperature, and density

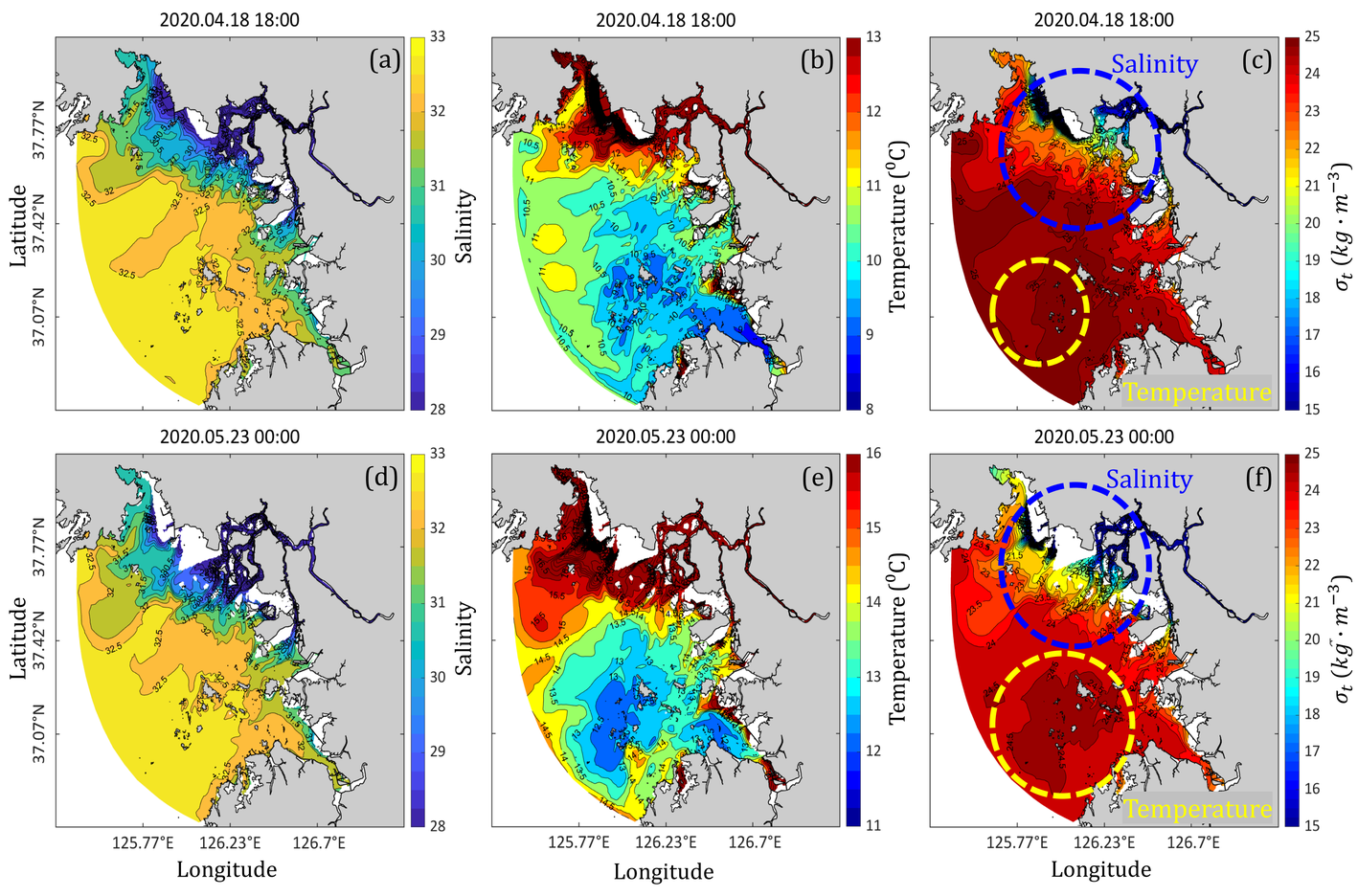


Figure 5. Map showing the horizontal distribution of salinity (a and d), water temperature (b and e) of FVCOM result, and calculated density (c and f) at the surface. The upper panels are result on April 18, 2020 and the bottom panels are result on May 23, 2020. The yellow circles are areas where have a similarity between water temperature distribution and density distribution at the surface. The blue circles are areas where have a similarity between salinity distribution and density distribution at the surface.

- ✓ In norther part of the Gyeonggi Bay, horizontal density distribution is similar with salinity
- ✓ On the other hand, horizontal density distribution at surface is similar with water temperature distribution in southern part of Gyeonggi Bay near Deokjeok island

Conclusions

- The contribution of water temperature to the density distribution of the adjacent regions of Deokjeok island in spring is comparable to that of salinity
- In the macrotidal estuary, local water temperature changes can cause some density gradients, but detailed analysis is required through comparison with long-term mooring data.

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