Data Assimilation and upstream open boundary Bias Correction in a regional model for the East Sea

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Introduction

Boundary conditions are important constrains on the interior solution when solving partial difference equations. Global prediction models have been used to provide boundary conditions for regional ocean models. However, in the Korea Strait, the simulated salinity by the global models was lower than the in-situ observation data in winter and higher in summer (Fig. 1). The simulated temperature from the global model also has biases with respective to the observation. These boundary biases have caused high uncertainties in the prediction of temperature and salinity distribution in the East Sea by nested regional ocean circulation models. To reduce prediction errors in the interior of the nested regional model domain, the open boundary bias correction (BC) and the data assimilation (DA) were performed using observation data.

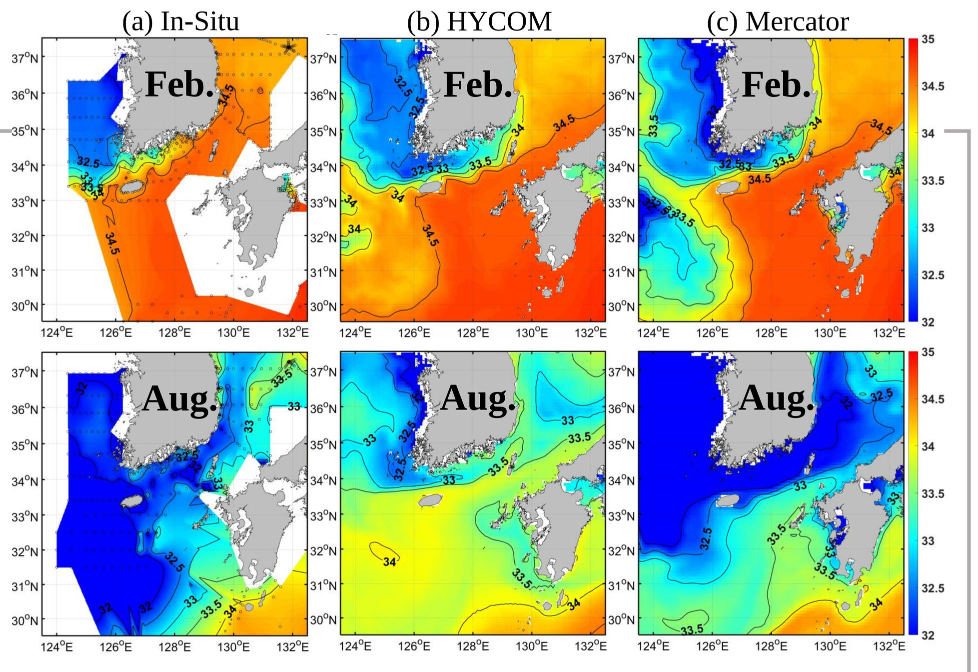

Fig. 1. Horizontal distribution of the monthly mean salinity at 10-m depth in February (upper panels) and August (lower panels) from (a) In-Situ observation, (b) HYCOM and (c) Mercator Ocean Model, respectively.

Data and Method

- **Numerical model**

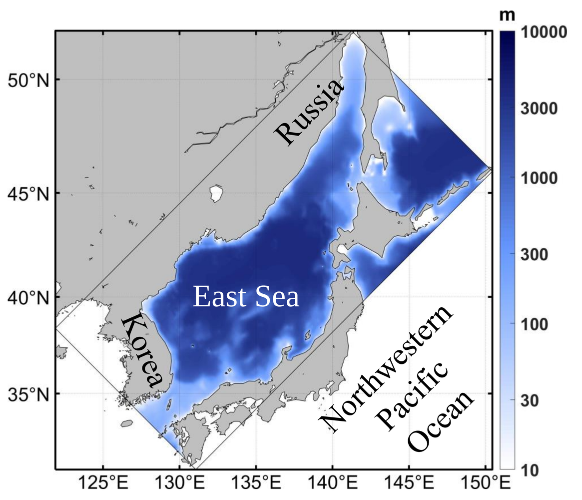

Fig. 2. Black rectangle are analysis model domain and blue shading represents bottom topography (m).

Regional Ocean Modeling System (ROMS)	
Grid spacing	3 km
Vertical layer	41 sigma layers
Initial condition	HYCOM v3.1
Open boundary	HYCOM v3.1 daily mean
Bathymetry	ETOPO5+Korbathy 30s
Atmospheric forcing	ECMWF ERA5 3 hourly
Tide	10 major constituent TPXO6
River	Nackdong, Tuman, Amur
Assimilation scheme	Ensemble Kalman Filter (EnKF)

- **Dataset for Bias correction and Data assimilation**

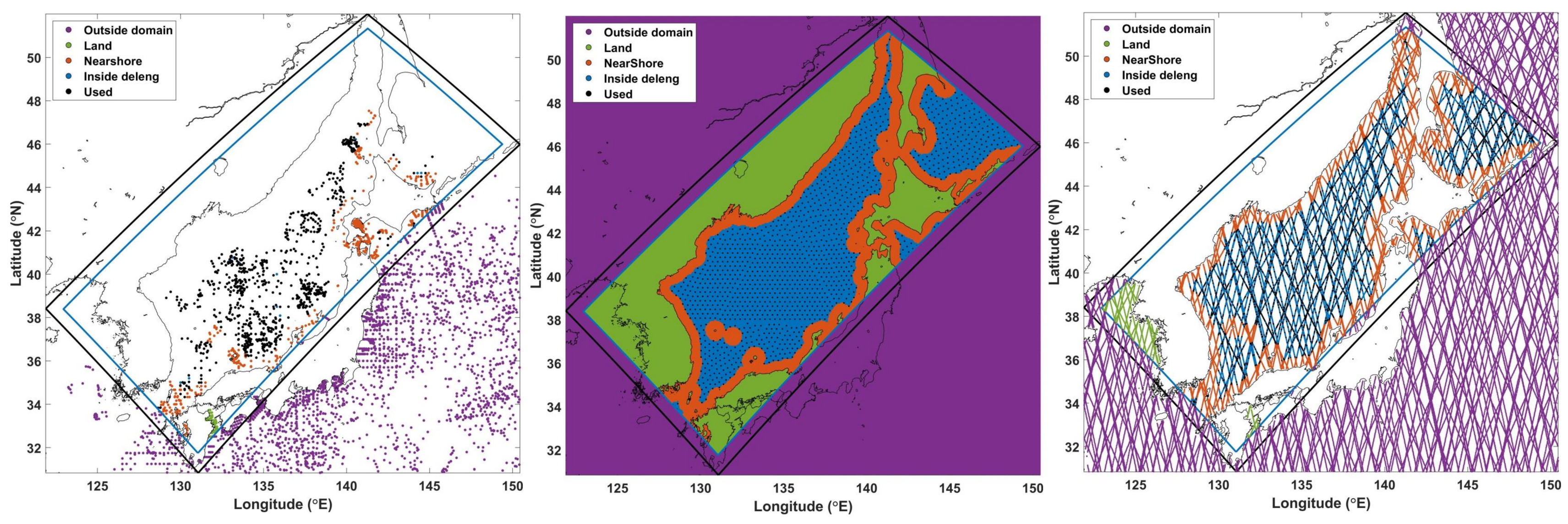

Fig. 3. Observation stations of temperature and salinity profile (left panel), sea surface temperature (middle panel) and along-track sea level anomaly (right panel) for the boundary correction and data assimilation. These dataset were obtained from NIFS, KHOA, KOEM, GTSPP and CMEMS, respectively.

- **Experiment design**

	exp.CTRL	exp.BC	exp.DA	exp.BCDA
Boundary correction	X	O	X	O
Data assimilation	X	X	O	O

Results

- **Bias between the observation data and global model**

- Surface temperature of HYCOM was higher than the observation during summer.
- HYCOM had cold bias in the bottom layer of the western channel of Korea Strait in August (Fig. 4).

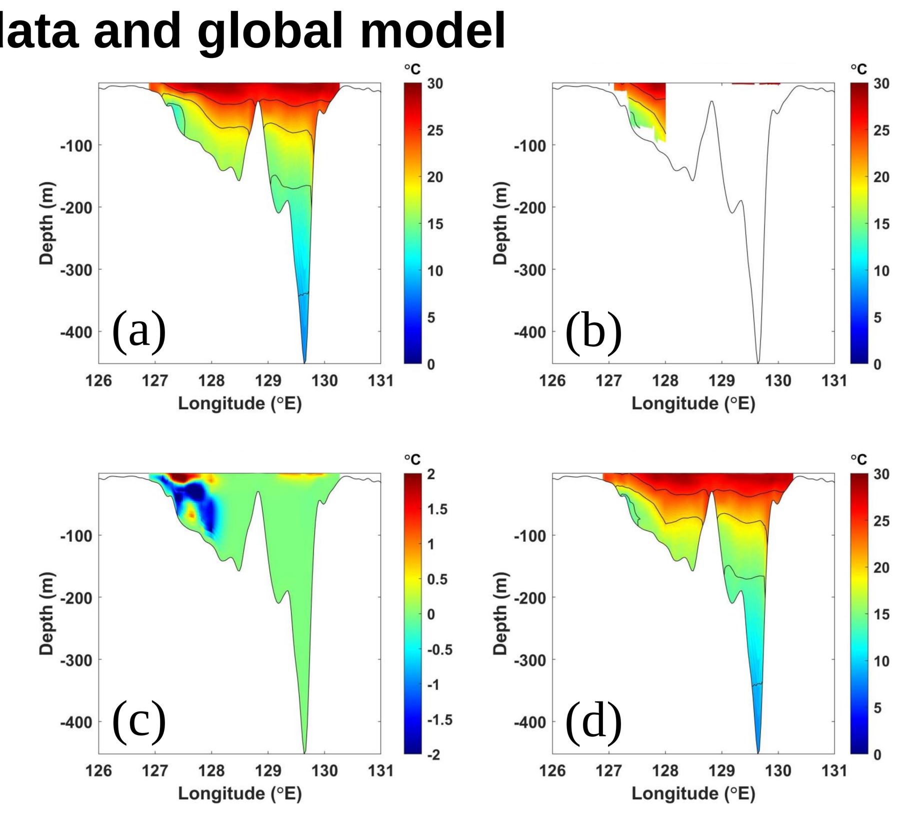

Fig. 4. Vertical section of temperature in August 2019 (a) no bias corrected, (b) observation, (c) bias, and (d) bias corrected along the open boundary in the Korea Strait.

- HYCOM salinity was lower than the observation along the south coast of the Korea in February.
- HYCOM salinity was higher than the observation at the western channel of Korea Strait in August (Fig. 5).

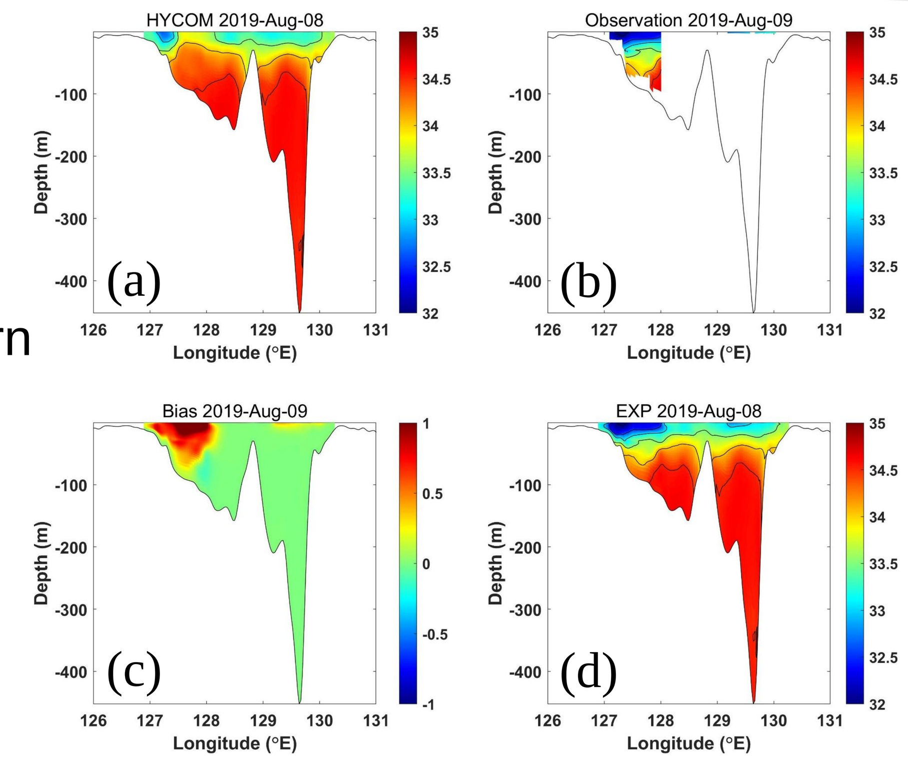

Fig. 5. Vertical section of salinity in August 2019 (a) no bias corrected, (b) observation, (c) bias, and (d) bias corrected at the open boundary across the Korea Strait.

- **Horizontal distribution of Temperature and Salinity**

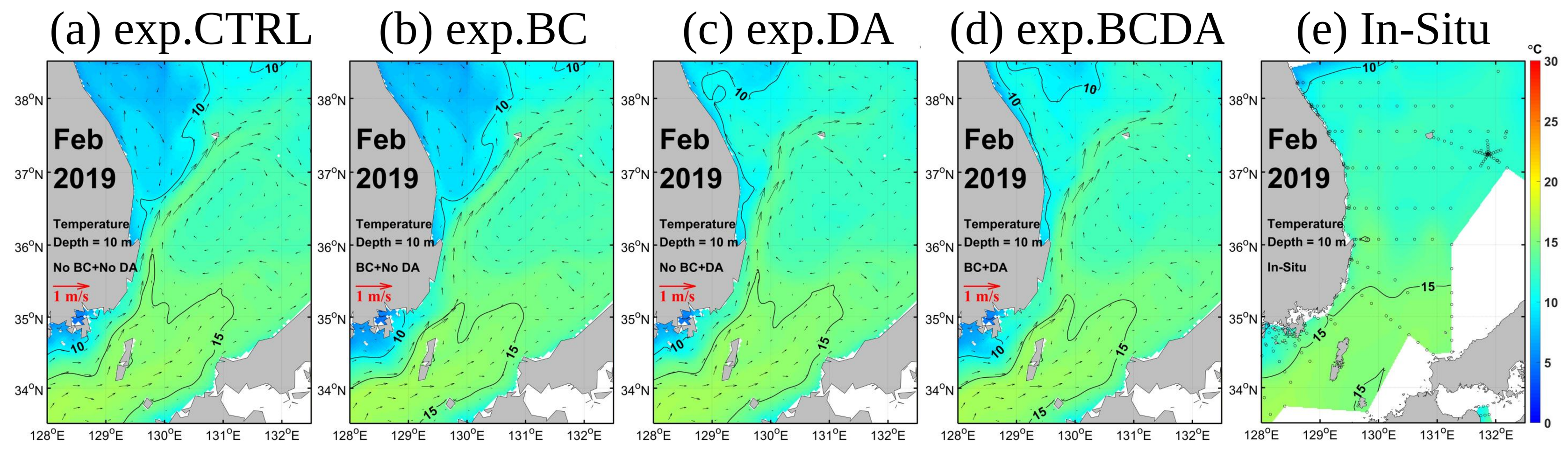

Fig. 6. Monthly mean temperature at 10-m depth in the East Sea in February 2019 from (a) exp.CTRL, (b) exp.BC, (c) exp.DA, (d) exp.BCDA and (e) In-Situ observation, respectively.

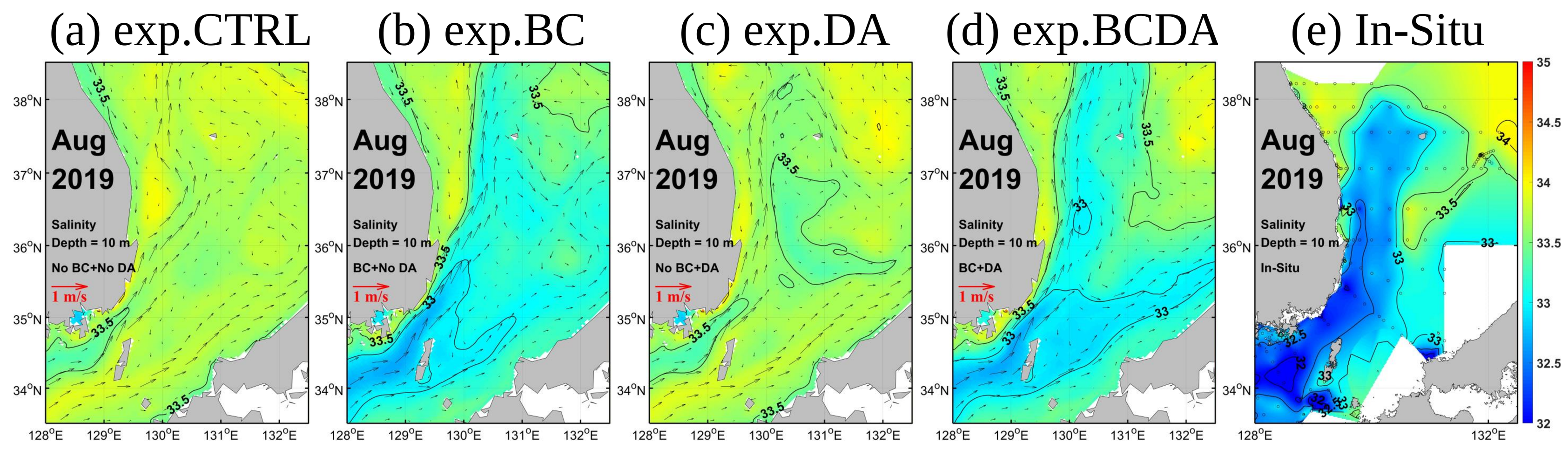

Fig. 7. Same as Fig. 6 except for salinity

- exp.DA and exp.BCDA simulated higher temperature than exp.CTRL and exp.BC in the northwestern Ulleung Basin in February 2019 (Fig. 6).
- In exp.BC and exp.BCDA, low salinity water (< 33.5) expanded from the Korea Strait to the Ulleung Basin in August 2019 (Fig. 7).

- **RMSEs temperature and salinity in the Ulleung Basin**

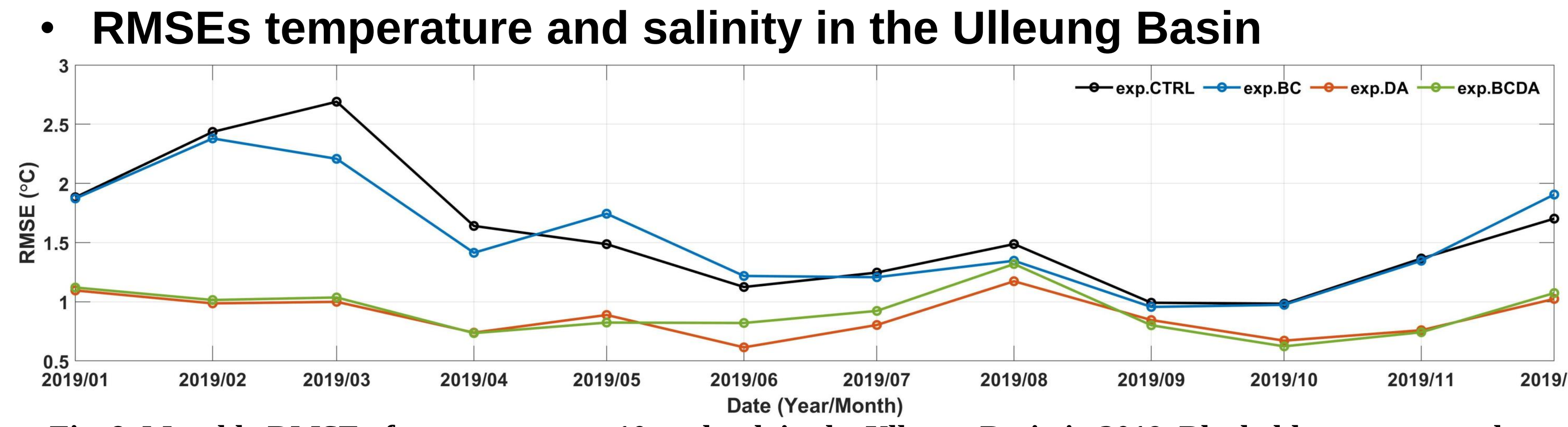

Fig. 8. Monthly RMSE of temperature at 10-m depth in the Ulleung Basin in 2019. Black, blue, orange and green lines represent the RMSEs from exp.CTRL, exp.BC, exp.DA and exp.BCDA, respectively.

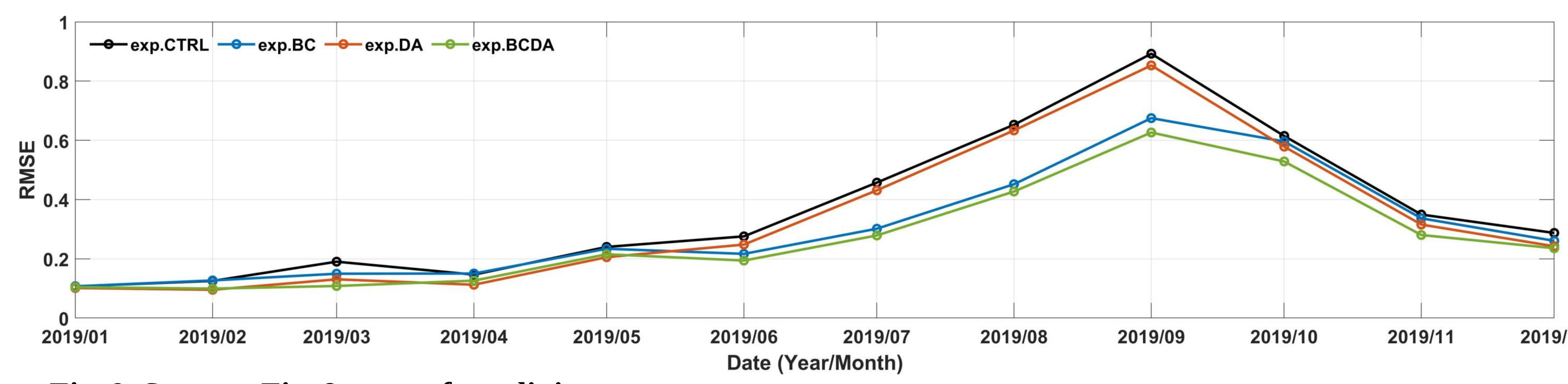

Fig. 9. Same as Fig. 8 except for salinity.

- The temperature RMSEs of exp.DA and exp.BCDA were relatively smaller in winter. Annual mean RMSEs of experiments CTRL, BC, DA, and BCDA were 1.59, 1.55, 0.88 and 0.92, respectively.
- The salinity RMSEs of exp.BC and exp.BCDA were relatively smaller in summer. Annual mean RMSEs of experiments CTRL, BC, DA, and BCDA were 0.36, 0.30, 0.33 and 0.27, respectively.

Conclusion

To reduce error of a nested regional model, open boundary data and interior solution were corrected using BC and DA, respectively. BC and DA were most effective at the Korea Strait in August and in the northwestern Ulleung Basin in February, respectively. BC and DA are expected to improve the interior solution of salinity and temperature in regional ocean models.