Applicability of AGRIF in the Regional Ocean Circulation Model

Hyeok Jin*, Heung-Bae Choi*, Young-Min Park*

*GeoSystem Research Corporation, Korea

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Advancing the science of ocean prediction

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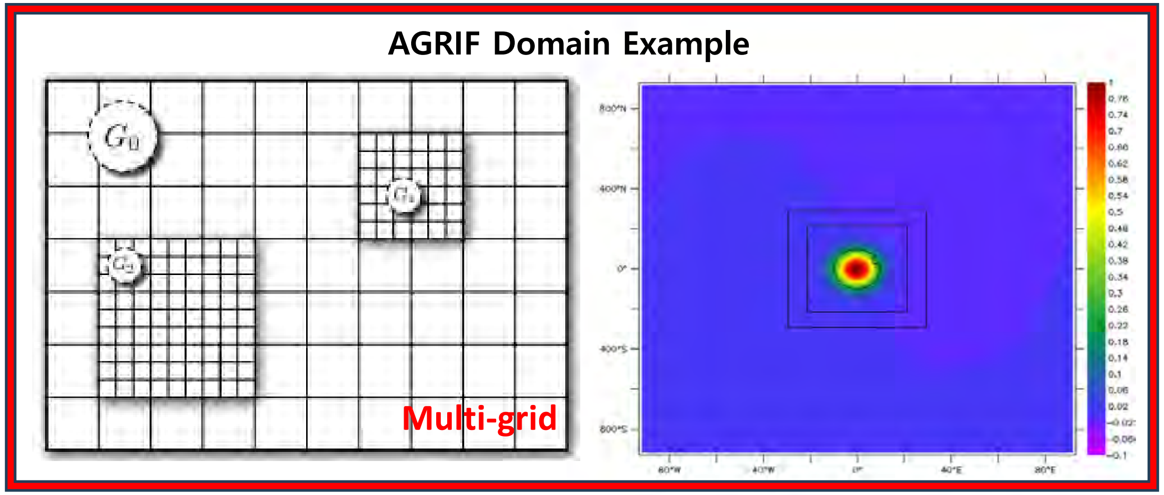
Objective

1. Applicability of AGRIF in the regional ocean circulation model (NEMO) and comparison with conventional nesting method

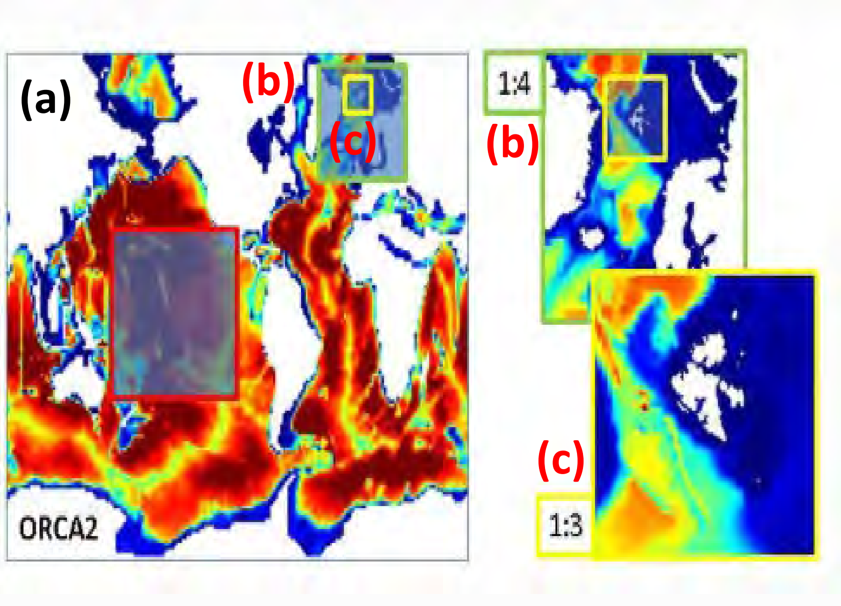
2. Comparative analysis of two nesting methods with different vertical coordinate systems

Introduction (AGRIF)



- **AGRIF(Adaptive Grid Refinement In Fortran)**

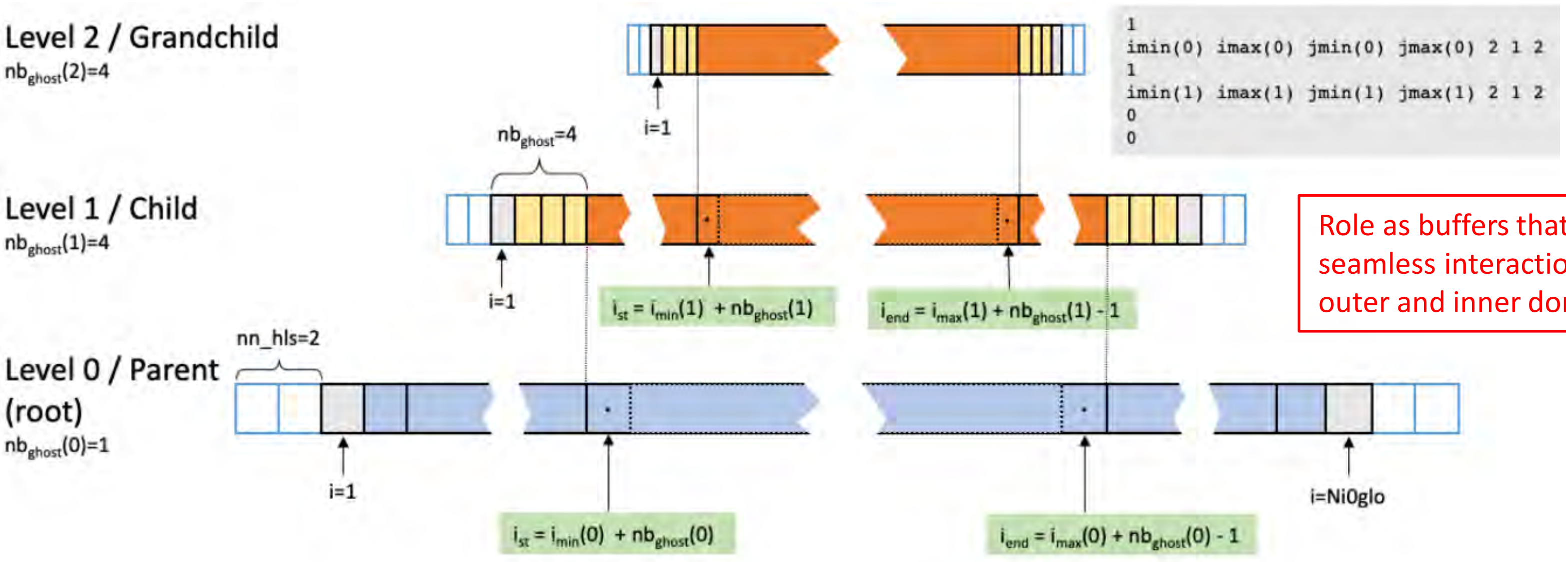
- Library designed to seamlessly refine both spatial and temporal grids for existing models
- Application to numerical models (ROMS, WRF, NEMO, etc.)
- Tool composed of CONV(unigrid -> multi-grid) and library for grids interactions
- One-way nesting (parent -> child: lateral boundaries)
- Two-way nesting (child <-> parent)



<Example of nested domains>

	Conventional nesting	Nesting with AGRIF
Preprocessing for boundary	O ((a) -> (b), (b) -> (c))	O (created in simulation)
Computational burden	Preprocessing and consecutive modeling for each domain	Integration of parent and other children models
Time resolutions of boundary values	Usually > 3hours	User definded (Dt), mostly smaller than conventional way
Spatial resolutions of boundary values	Approx. 0.08 deg (8~9km) (MYOCEAN, HYCOM)	Depending on parent grid and refinement factor (usually lower than 5 to maintain stability)
Two-way nesting	X (only one-way)	O

Introduction (AGRIF)



Role as buffers that allow for seamless interaction between outer and inner domain

<Configuration of nested grid with ghost cells>

```
-bash>> cat AGRIF_FixedGrids.in
1
110 180 140 230 4 4 1
0
```

i (180 - 110) * 4 = 280.

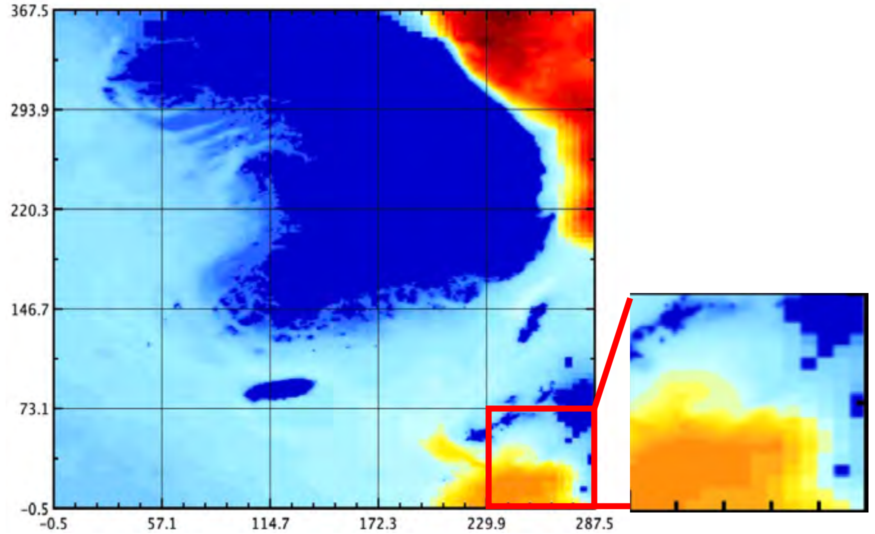
j (230 - 140) * 4 = 360

```
dimensions:
  x = 288;
  y = 368;
  z = 51;
  t = UNLIMITED;   // (1 currently)
variables:
  float nav_lon(y=368, x=288);

  float nav_lat(y=368, x=288);

  float nav_lev(z=51);
```

<Example of grid refinement with AGRIF>



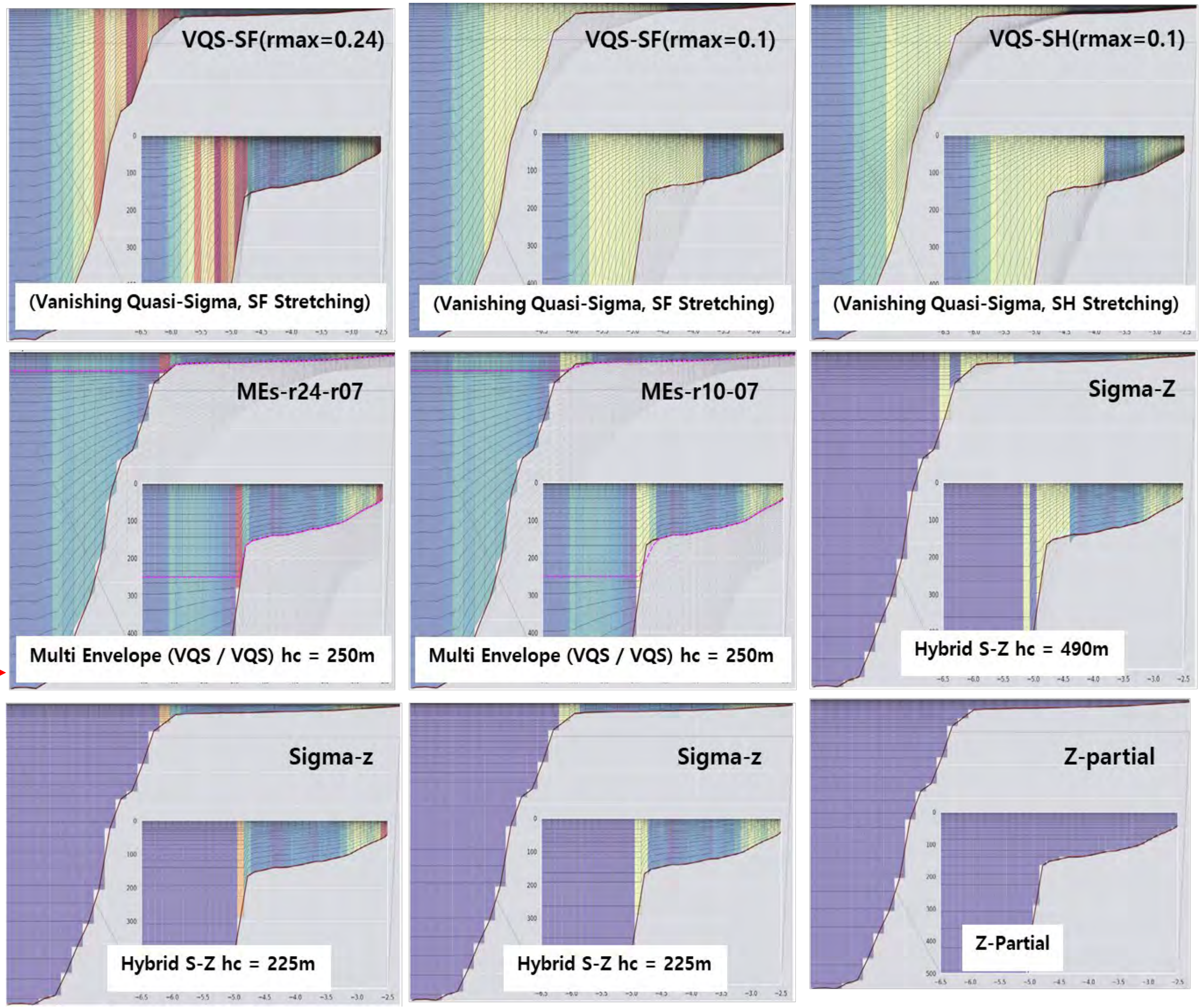
<Ghost cells applied to domain bounderies>

Introduction (Nemo) and objective

NEMO v.4.2.1

- State-of-the-art modelling framework of ocean-related engines for research activities and forecasting services in oceanography and climatology
- Availability for global and regional ocean modeling
- Fundamental engine for **"blue ocean"** composed of the primitive equations of the ocean(thermo)dynamics
- Supplementary engine for "white ocean (sea-ice)" and **"green ocean (biochemical process)"**
- Data assimilation interface, ocean-atmosphere coupling, seamless embedded zooms with **the AGRIF 2-way nesting package**
- Horizontal direction: curvilinear orthogonal grid with Arakawa C-type grid
- **Vertical direction: a full or partial step z-coordinate, or s-coordinate, or a mixture of the two**
- HPC functionalities

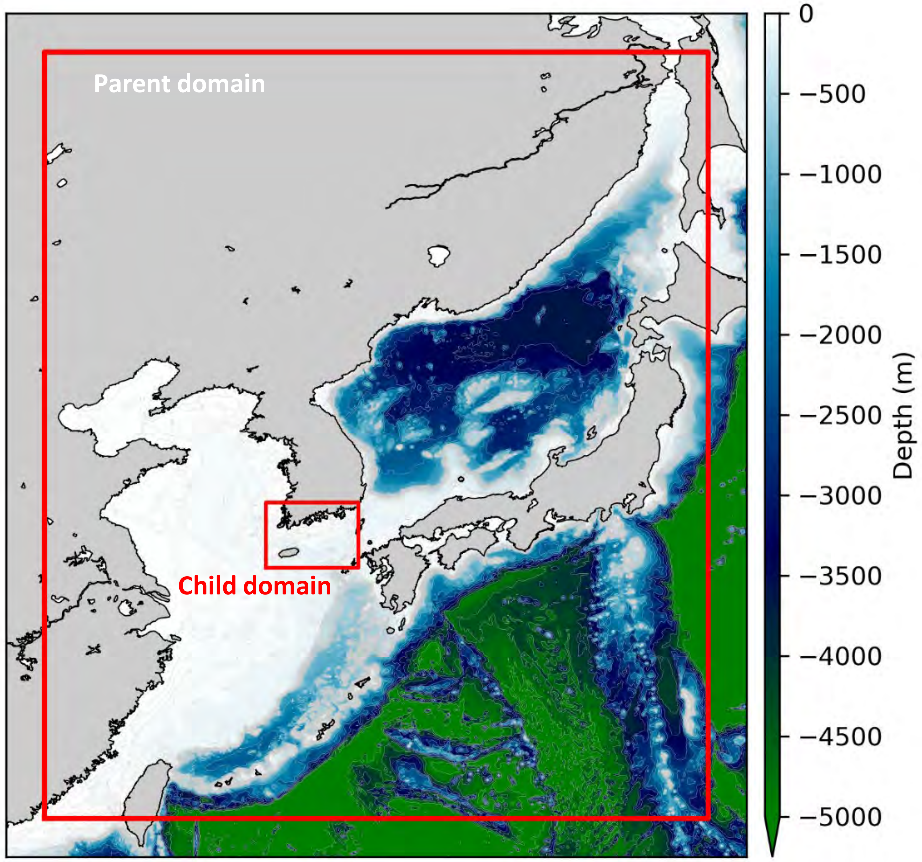
All compatible



<Example of various vertical coordinates (Wise et al., 2022)>

Numerical setup

<Summary of model domain>



	Parent model	Child model
Spatial resolutions	1/16°(6km, 415×479)	1/48°(2km, 175×124)
Area	117~142.94°E, 23.0~52.94°N	125.67~129.27°E, 32.79~35.34°N
Vertical level	51	51
Atmospheric Forcing	ERA5(0.25°×0.25° level grid spacing) 3 hourly data	ERA5(0.25°×0.25° level grid spacing) 3 hourly data
Open boundary	MYOCEAN (0.083°×0.083°×51 level grid spacing) daily mean data	-
Tidal forcing	TPXO8 (M_2, M_4, S_2, O_1, K_1, N_2, K_2, P_1, Q_1)	-
River runoff	RivDIS climatology (Yangtze river)	-
Bathymetry	GEBCO_2023 (0.00416°×0.00416°)	GEBCO_2023 (0.00416°×0.00416°)

Numerical setup

Experiments

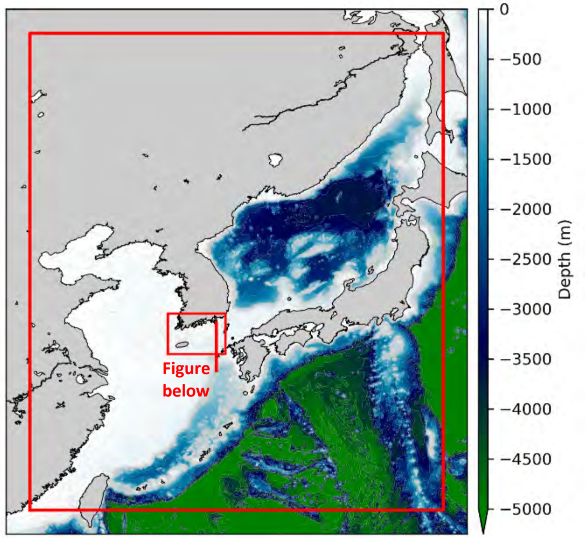
CASE1 : 51 z-levels with partial step (MYOCEAN open boundary)

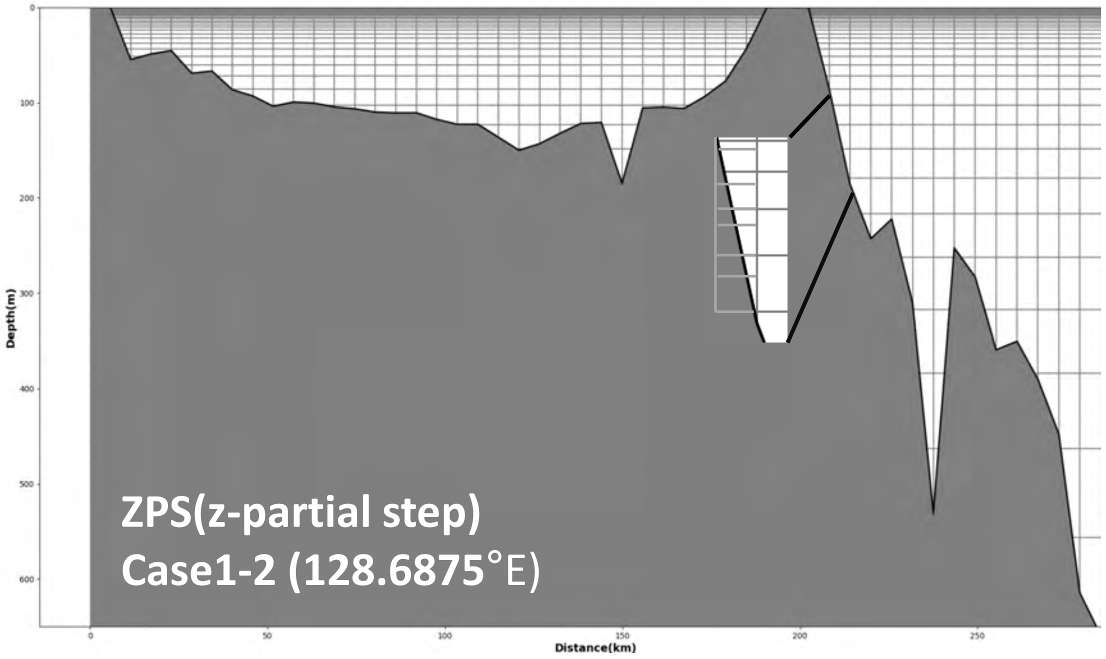
CASE2 : 51 z-levels with partial step (open boundary from parent model (6km))

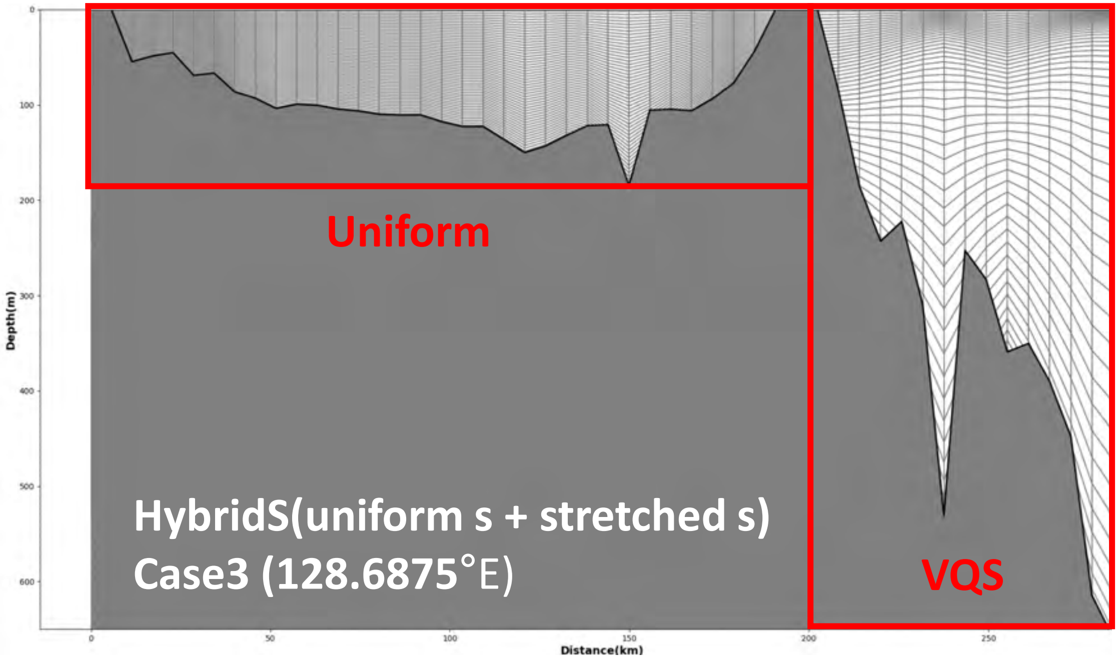
CASE3 : 51 levels with Vanishing Quasi-Sigma (open boundary from parent model (6km))
(rmax = 0.07, hc(critical depth for transition to stretched coordinates) = 170m)

$$r = \frac{|\delta H|}{2\bar{H}}$$

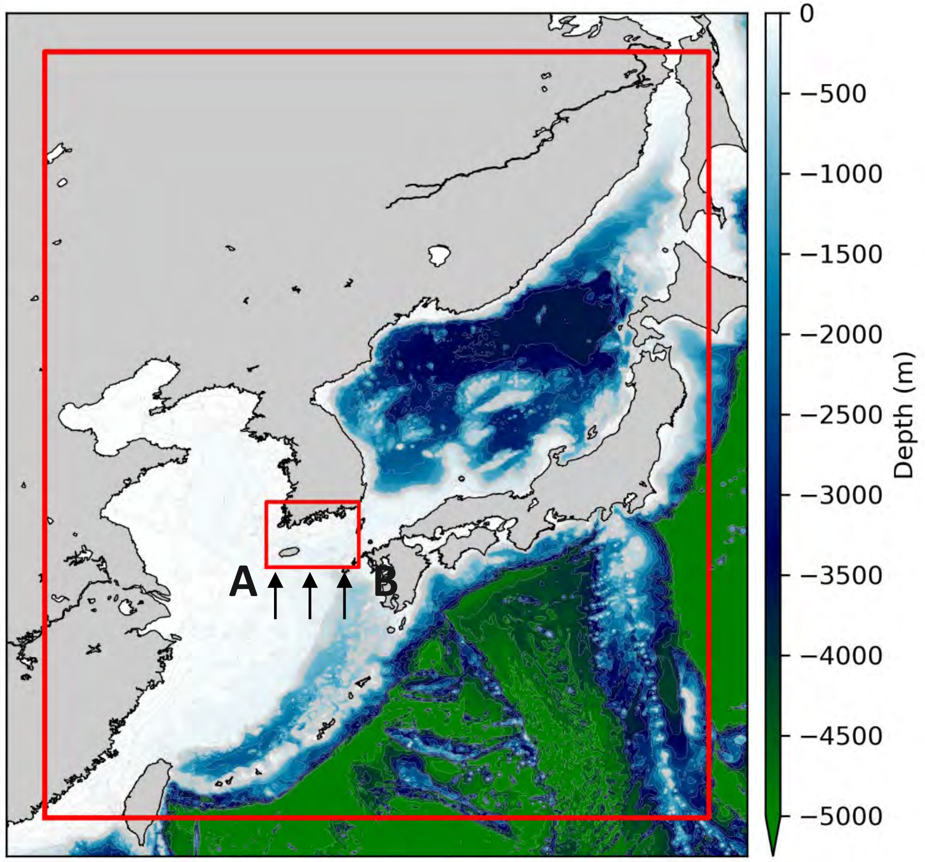
*Period for analysis: 2022.07.01 – 08.31 (2 months)

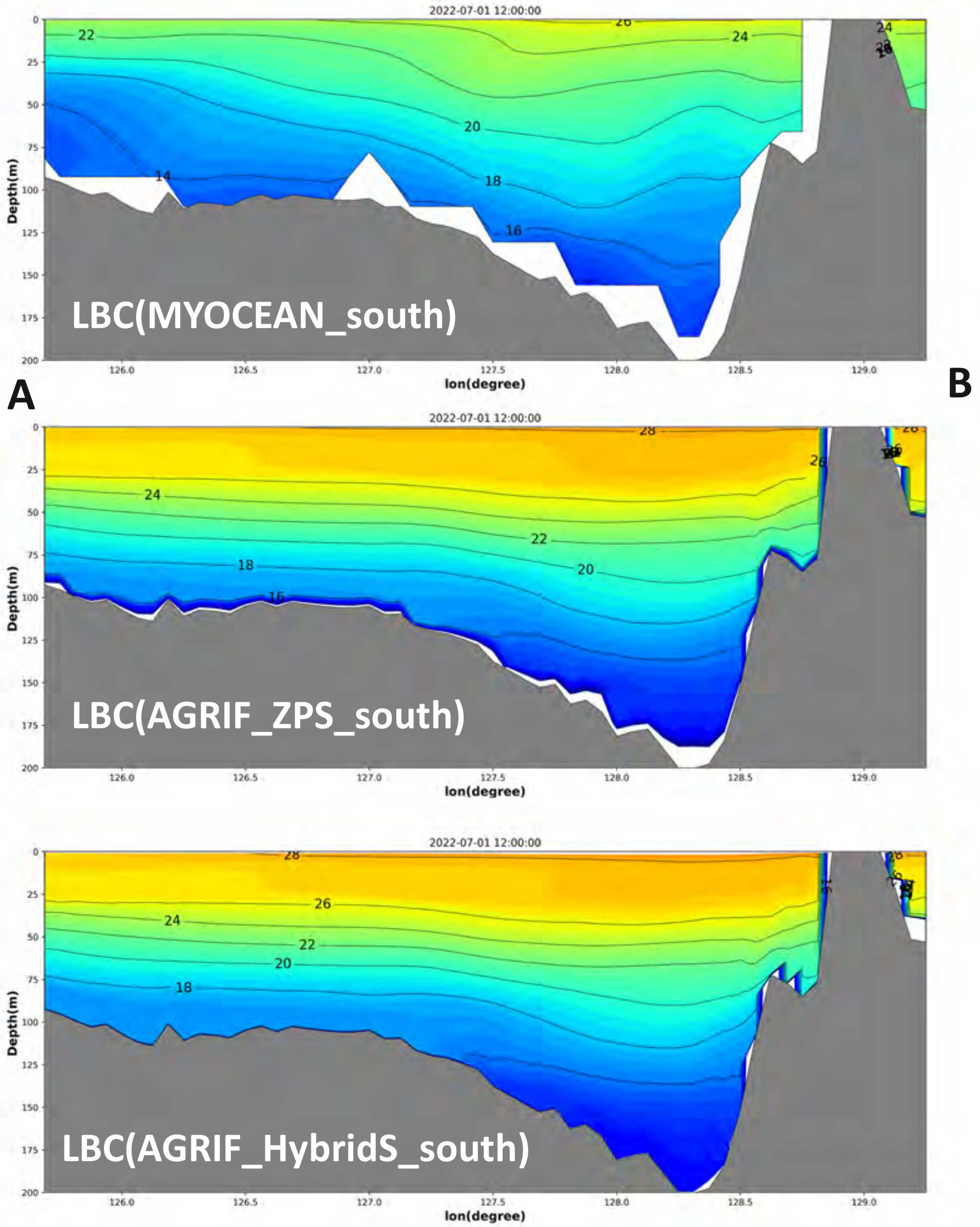




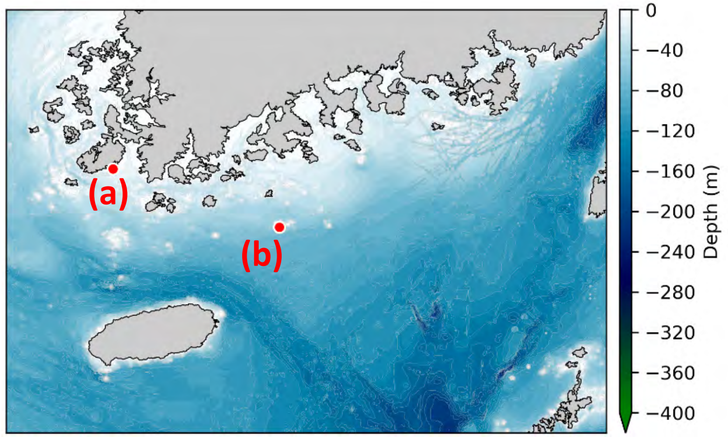


Result(Lateral boundary)

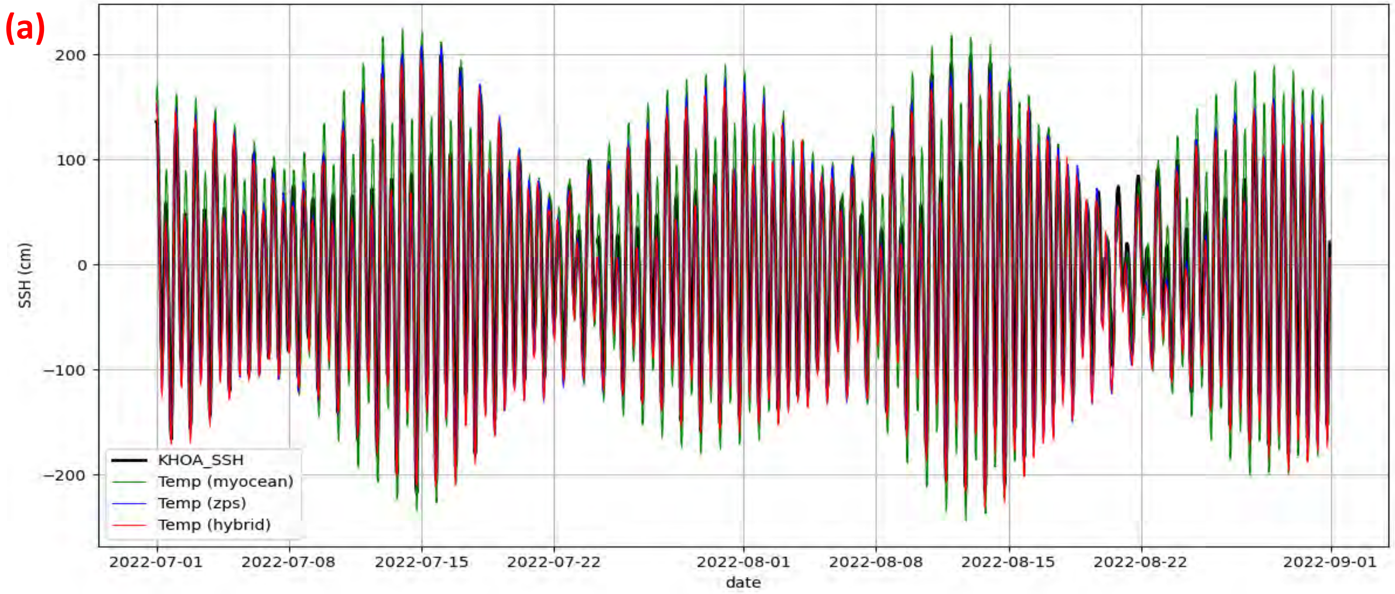


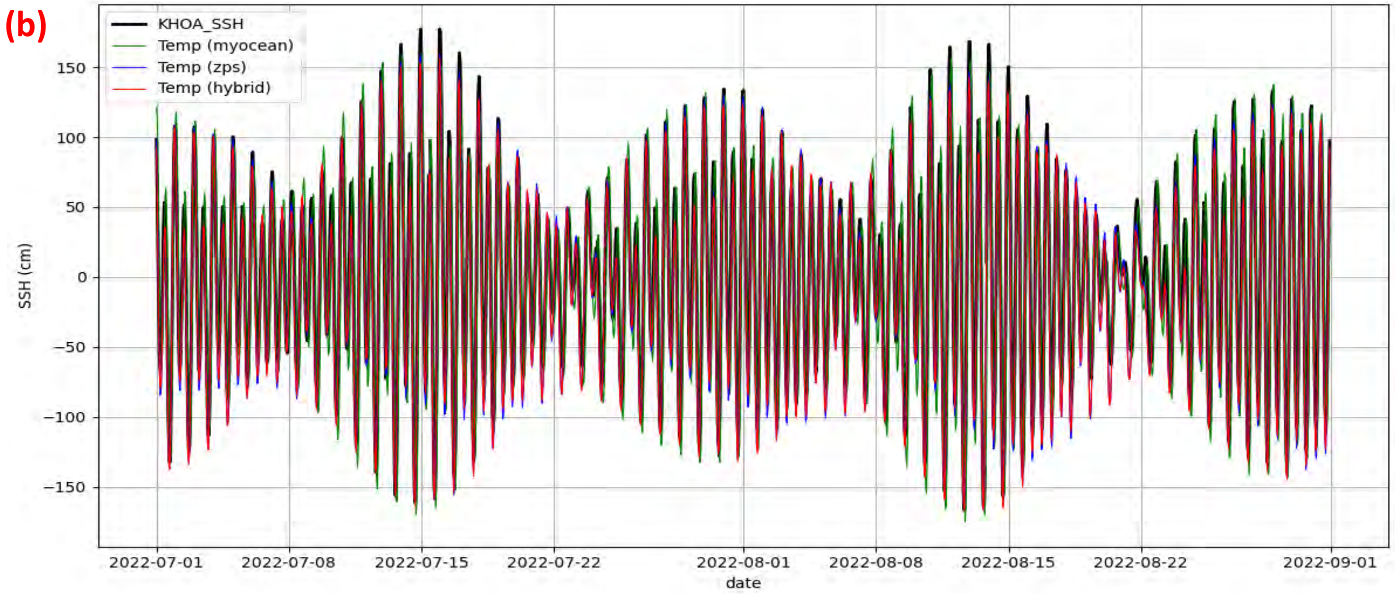


Result (hourly sea surface height)

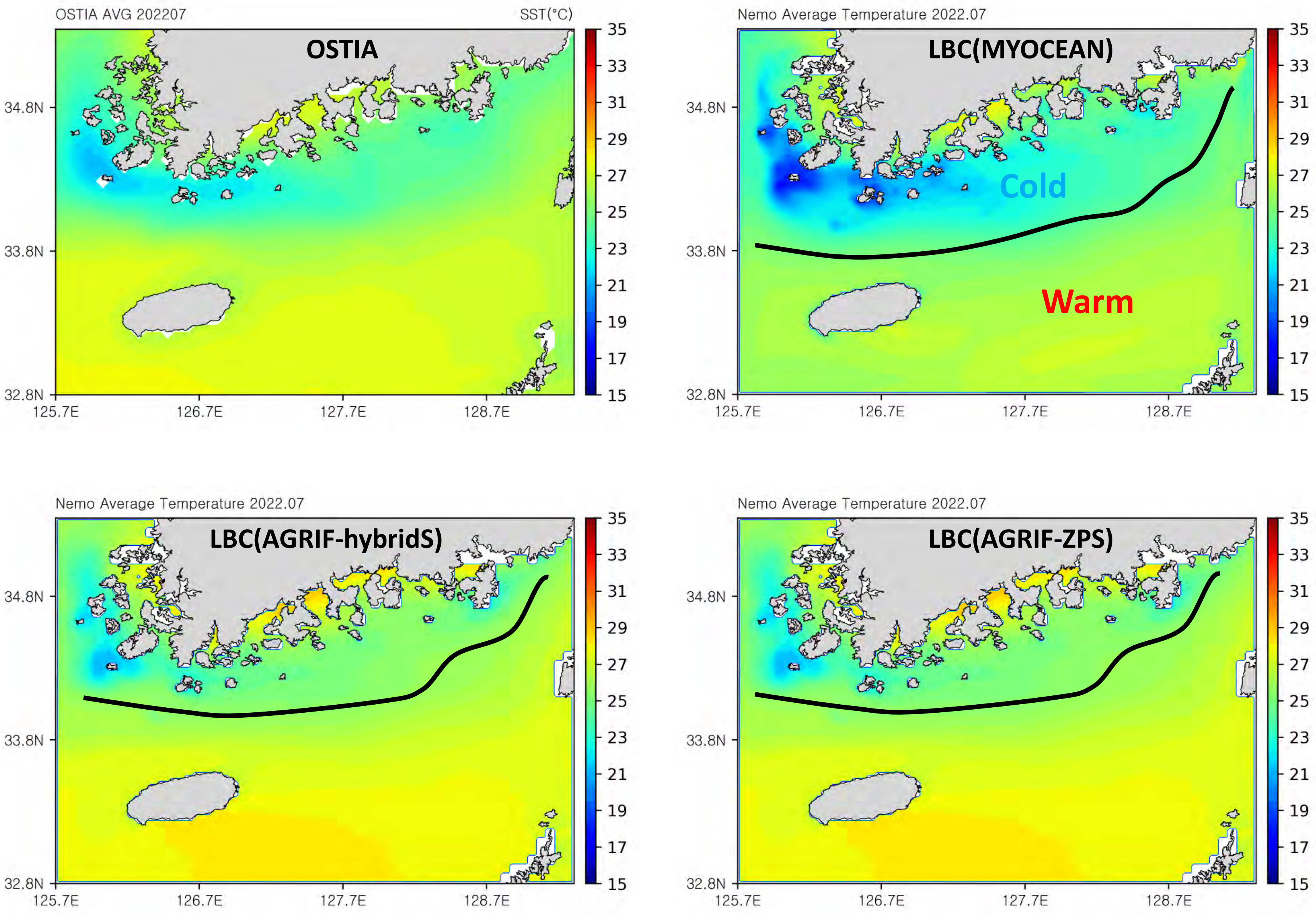


station	Boundary	Corr	RMSE (cm)	BIAS (cm)
(a)	MYOCEAN	0.96	30.08	-5.45
	AGRIF(zps)	0.98	20.88	-13.13
	AGRIF (hybrids)	0.98	23.27	-14.52
(b)	MYOCEAN	0.95	45.82	-4.26
	AGRIF(zps)	0.98	15.97	-9.0
	AGRIF (hybrids)	0.98	18.67	-11.32

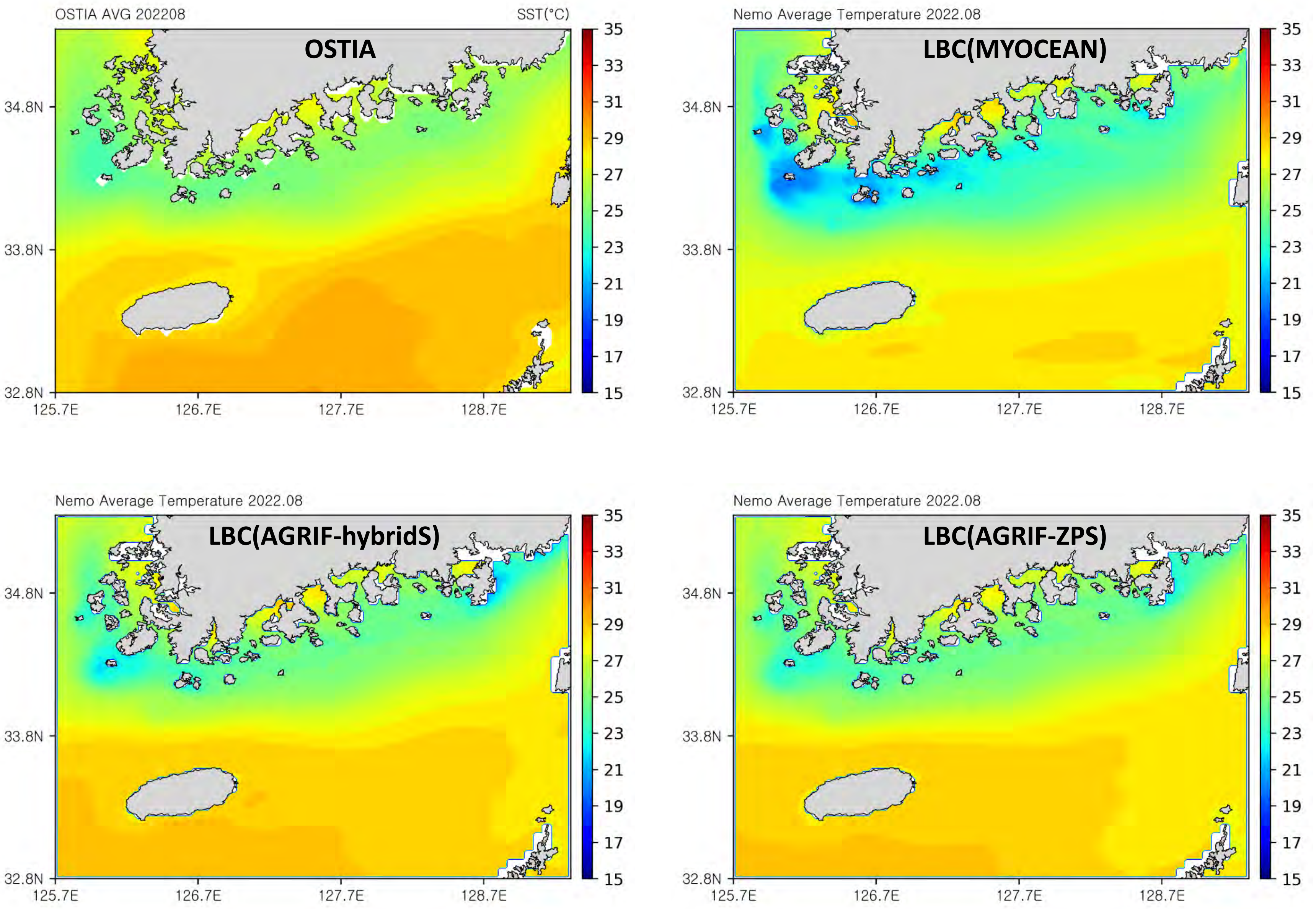




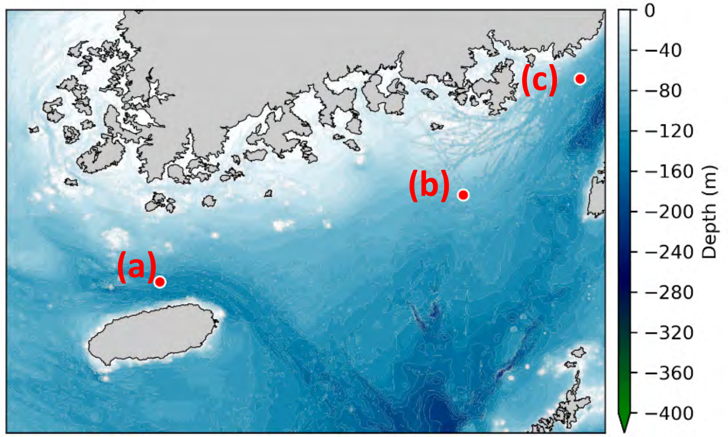
Result (Temperature)



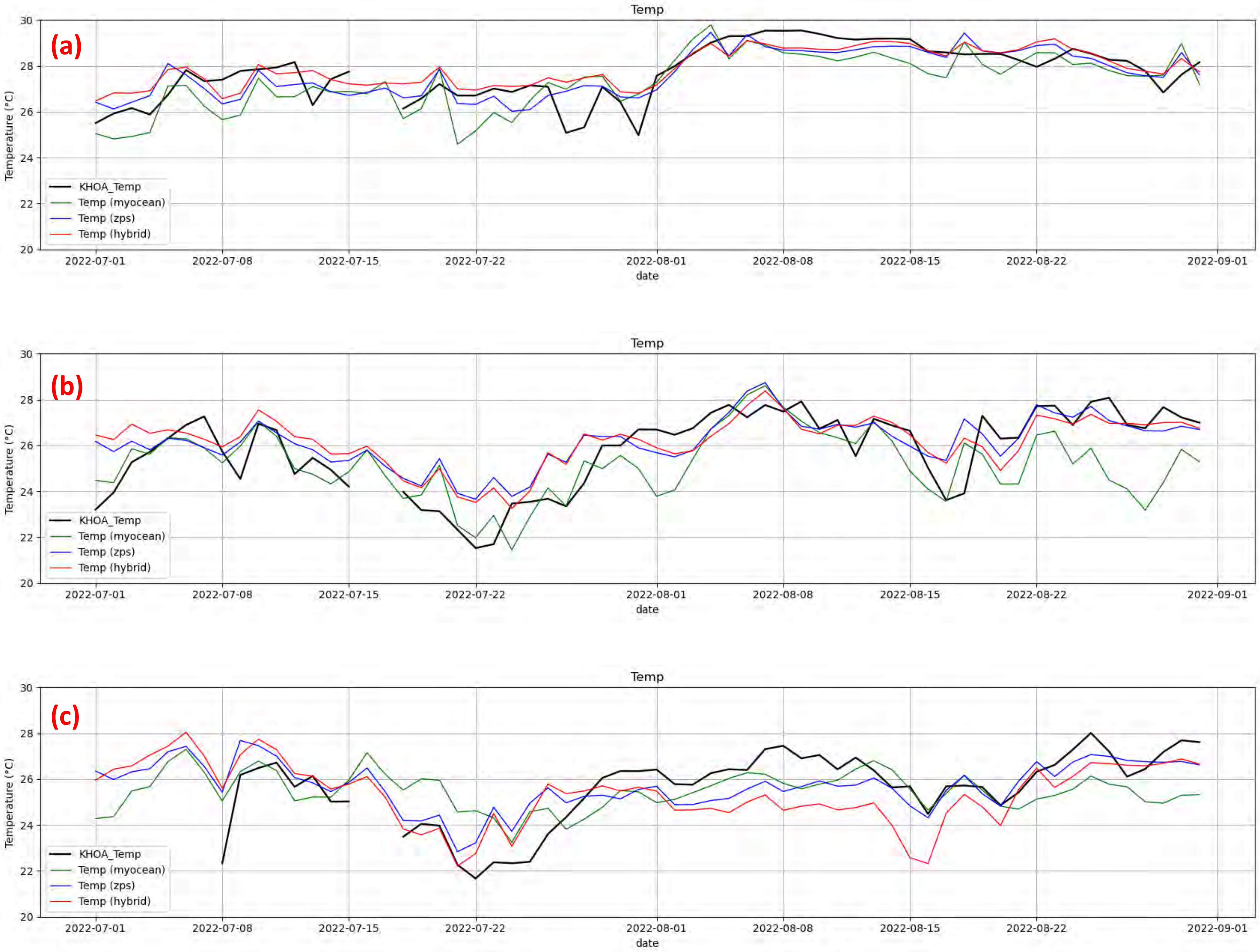
Result (Temperature)



Result (daily mean temperature)

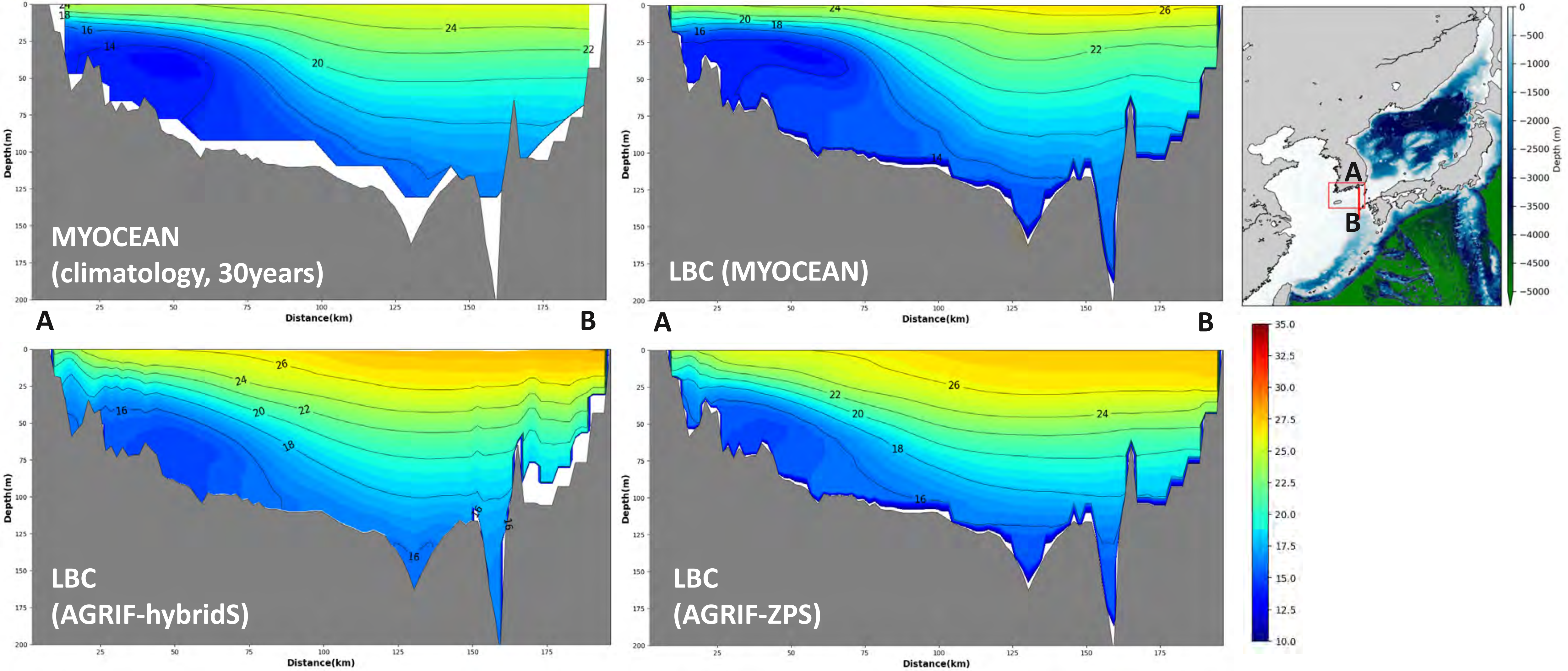


station	Boundary	Corr	RMSE (°C)	BIAS (°C)
(a)	MYOCEAN	0.72	2.1	-1.9
	AGRIF(zps)	0.79	0.73	-0.04
	AGRIF (hybrids)	0.83	0.73	0.21
(b)	MYOCEAN	0.68	2.47	-2.1
	AGRIF(zps)	0.78	1.18	0.39
	AGRIF (hybrids)	0.78	1.18	0.41
(c)	MYOCEAN	0.56	2.14	-1.7
	AGRIF(zps)	0.74	1.07	-0.01
	AGRIF (hybrids)	0.59	1.38	-0.43



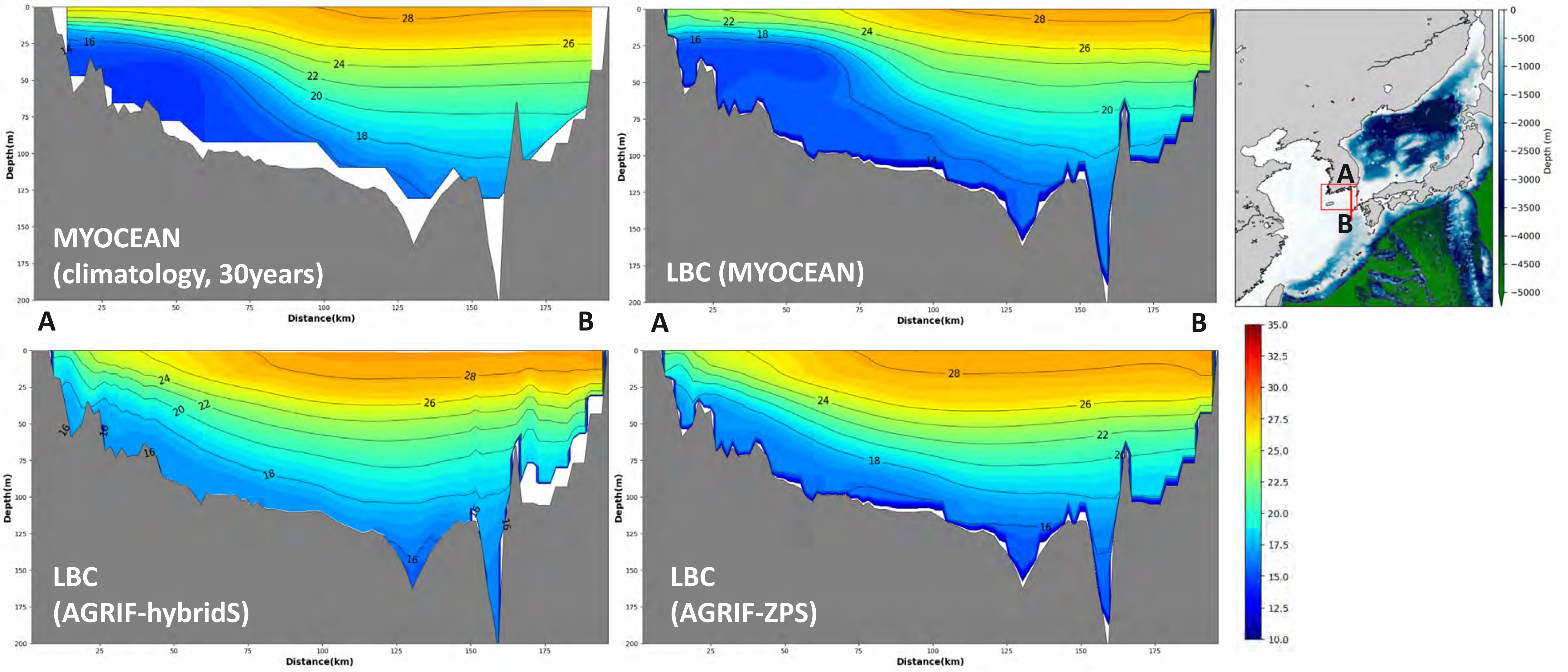
Result (Temperature in vertical direction)

2022.07 average(128.695°E)

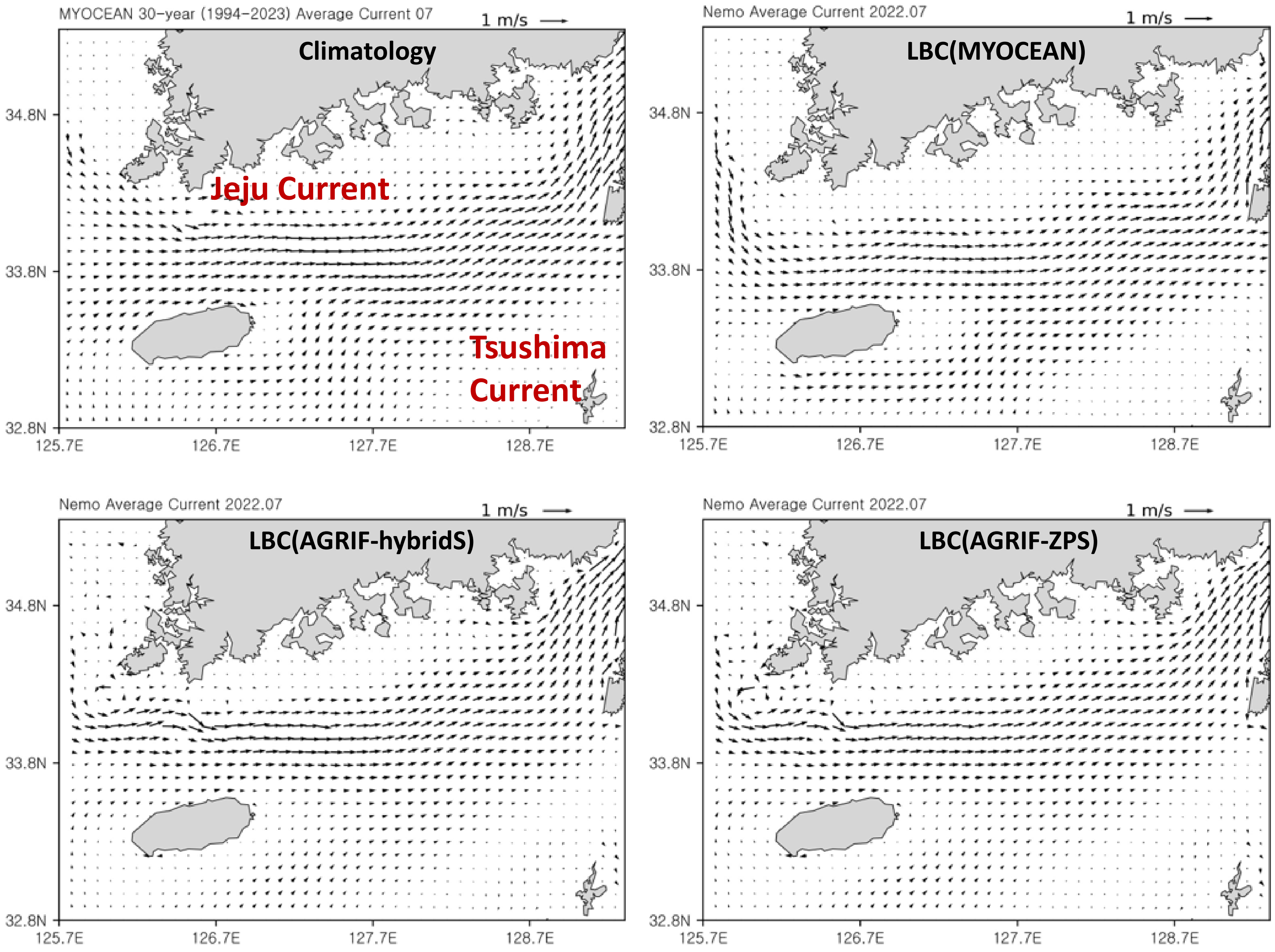


Result (Temperature in vertical direction)

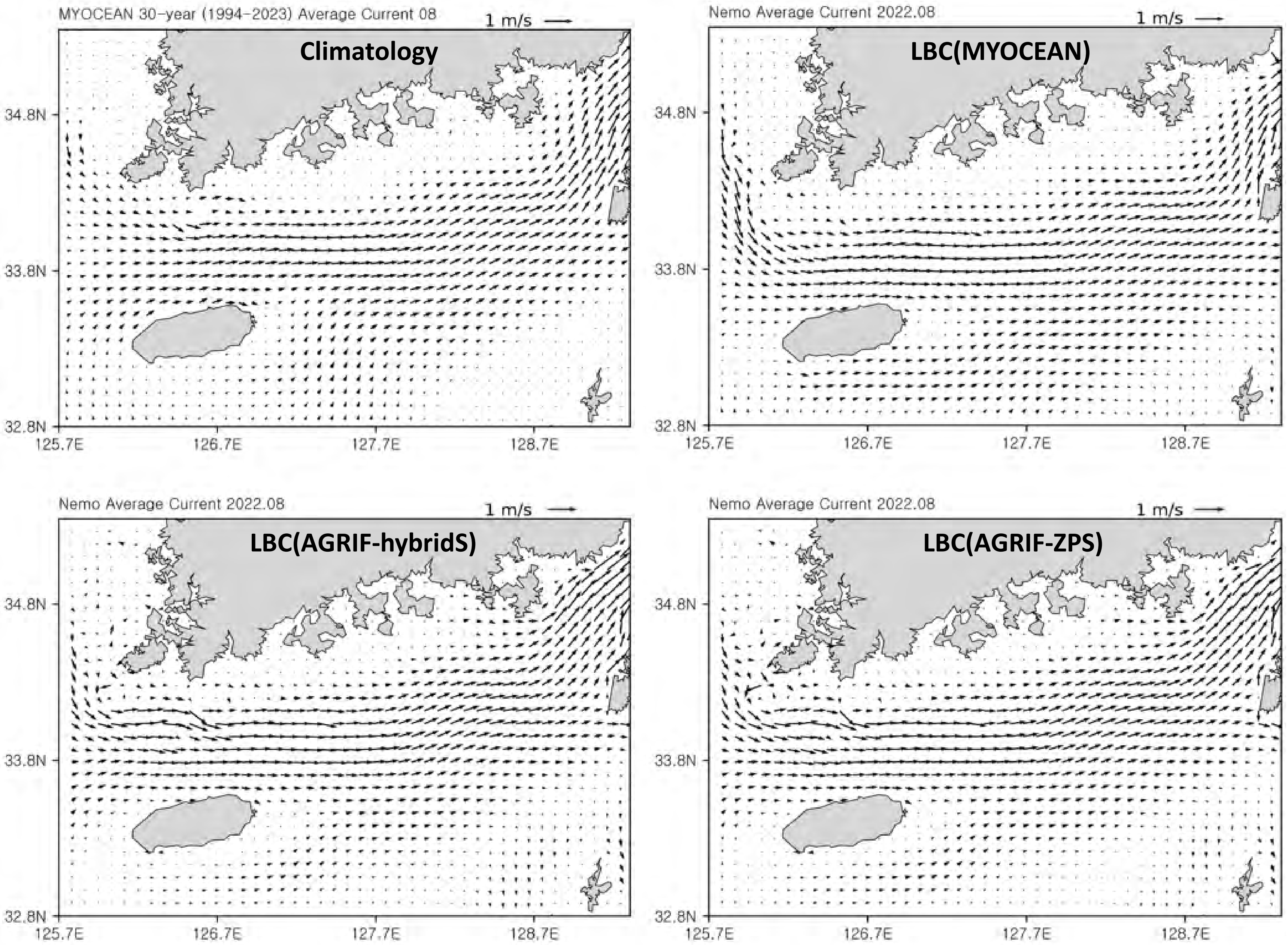
2022.08 average(128.695°E)



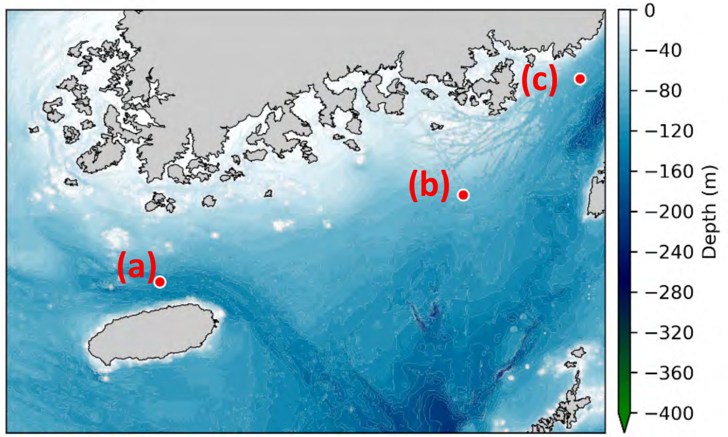
Result (Current)



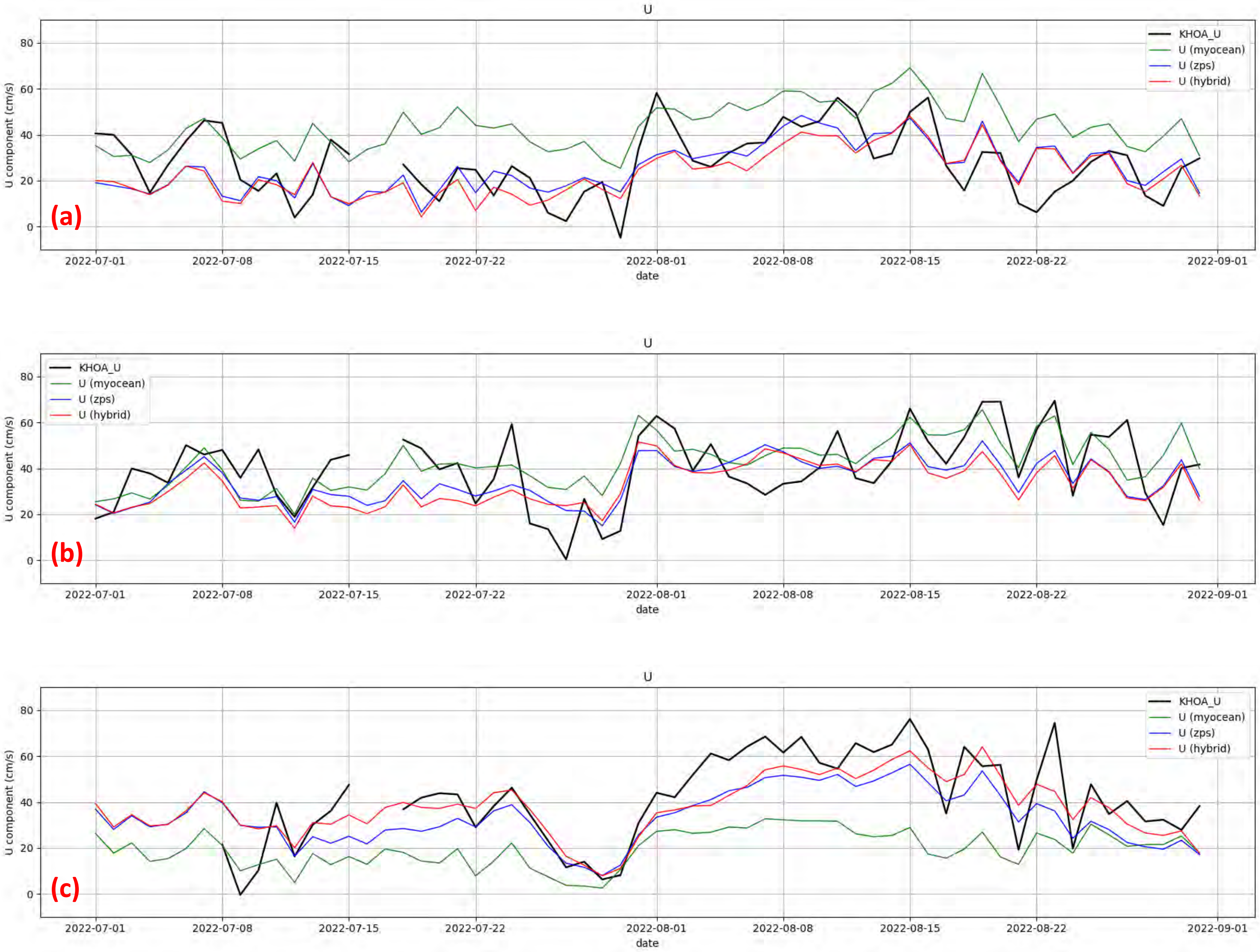
Result (Current)



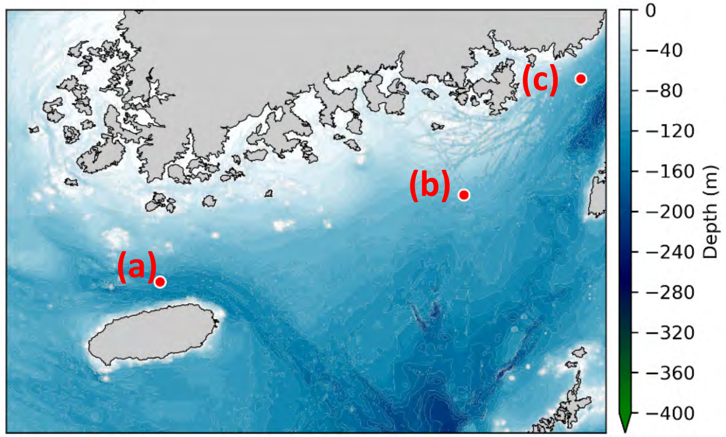
Result (daily mean U-component)



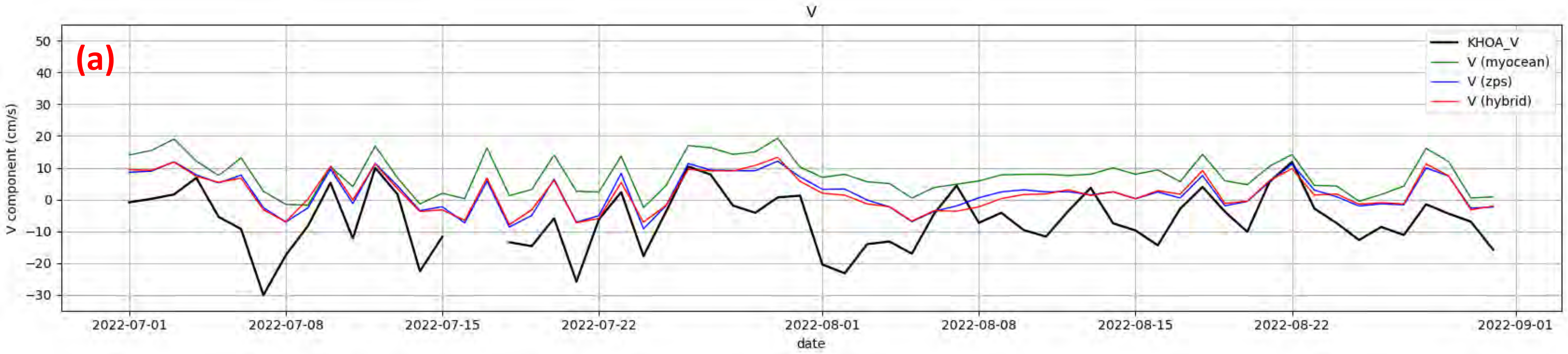
station	Boundary	Corr	RMSE (cm/s)	BIAS (cm/s)
(a)	MYOCEAN	0.55	19.94	15.83
	AGRIF(zps)	0.51	12.72	-1.99
	AGRIF (hybrid)	0.52	13.17	-4.18
(b)	MYOCEAN	0.61	12.73	2.66
	AGRIF(zps)	0.61	13.43	-5.05
	AGRIF (hybrid)	0.55	14.75	-6.72
(c)	MYOCEAN	0.75	26.73	-21.68
	AGRIF(zps)	0.81	13.91	-7.86
	AGRIF (hybrid)	0.82	11.58	-3.06

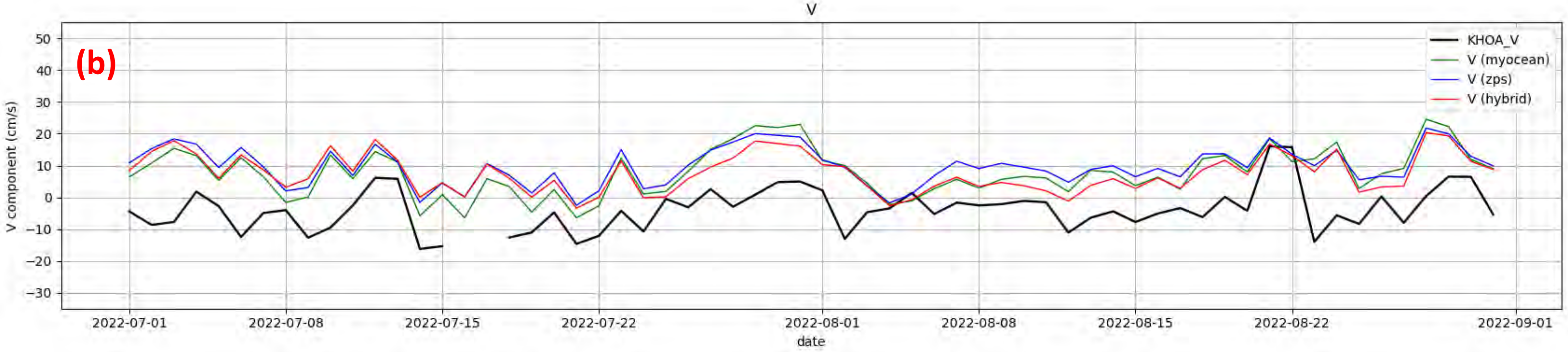


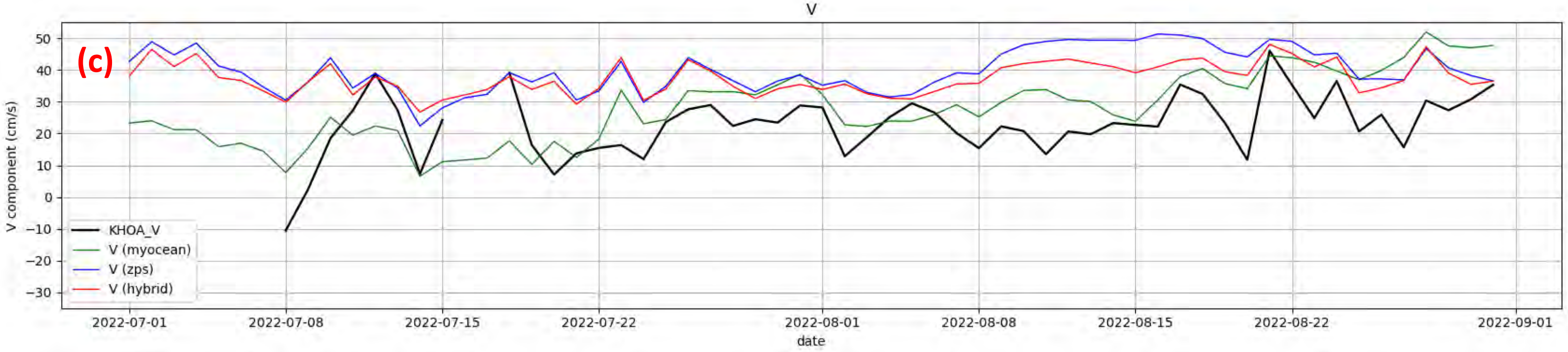
Result (daily mean V-component)



station	Boundary	Corr	RMSE (cm/s)	BIAS (cm/s)
(a)	MYOCEAN	0.67	15.56	14.00
	AGRIF(zps)	0.70	10.83	8.62
	AGRIF (hybrid)	0.69	10.78	8.52
(b)	MYOCEAN	0.54	13.71	11.92
	AGRIF(zps)	0.54	15.01	13.69
	AGRIF (hybrid)	0.48	13.23	11.48
(c)	MYOCEAN	0.55	11.92	6.81
	AGRIF(zps)	0.35	19.60	17.01
	AGRIF (hybrid)	0.42	16.99	14.46







Summary and discussion

Summary

- SSH: results of SSH demonstrated a strong correlation (>=0.96) with observations (Corr >= 0.96) across all experimental cases while overall negative bias is shown
- Temperature: results with direct MYOCEAN boundary underestimated SST compared to observations, which stems from the boundary's underestimation. AGRIF results show better performance of area and point comparisons while influence of vertical grids in the present domain are not dramatic
- Current: results of all experiments well captured Jeju and Tsushima warm current but AGRIF tends to show a better agreement with buoy observations

Future plans

- AGRIF tool and data assimilation to create forecasting models for various regional area and ports with higher resolutions after more thorough sensitivity test for all seasons including East (Japan) and Yellow sea
- Best compromise between model resolutions and computational time for the purpose of operational models since AGRIF requires more computational resources than a single model

Thanks for listening

Q & A

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*GeoSystem Research Corporation, Korea

E-mail : hyeokjin@geosr.com