SYMPOSIUM OP'24 ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

KIOST KOREA INSTITUTE OF OCEAN SCIENCE & TECHNOLOGY

Observational systems

# Strategy and validation for determining the location of ocean observation buoys

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## Introduction

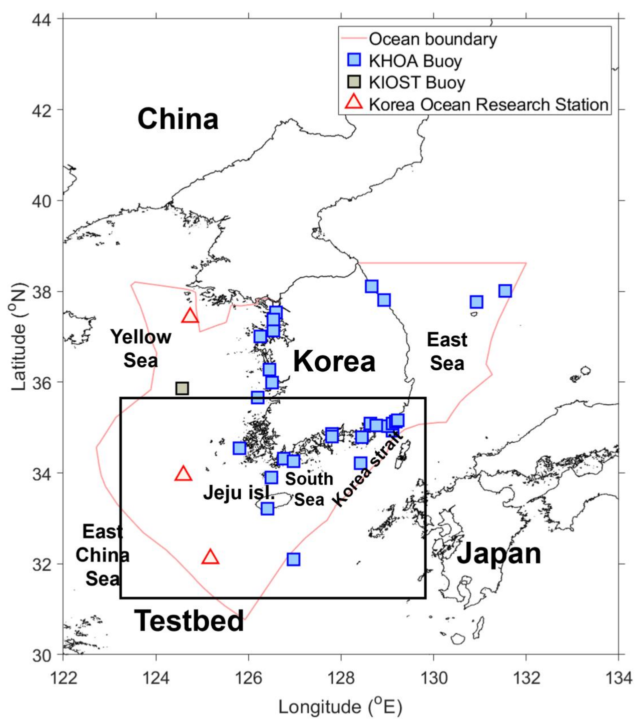
- ✓ The deployment and operation of ocean buoys incur significant costs, necessitating a meticulous approach to site selection.
- ✓ Currently, ocean buoys operating in Korean territorial waters are primarily concentrated in shallow coastal areas, resulting in a significant decline in observation density towards the open sea.
- ✓ Consequently, this creates extensive observation gaps, highlighting the need for technical guidelines to prioritize the placement of new observation buoys

## Objectives

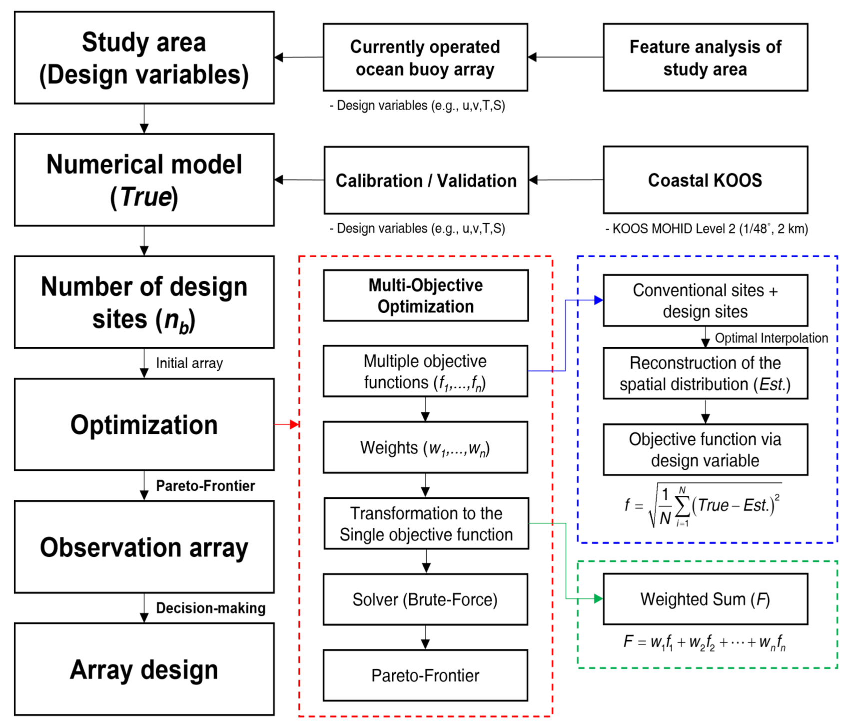
- ✓ This study establishes a testbed in the South Sea of Korea and employs an optimization technique to determine the placement of new observation buoys in specific areas, considering the existing ocean buoy observation network operated by various relevant agencies.
- ✓ The validity of the placement is verified based on OSSEs (Observing System Simulation Experiments) and data acquired from the actual deployment of new observation buoys within designed areas.

## Methodology

- ✓ **[Step 1] Selection of Target Area:** The selected testbed is the South Sea of Korea
- ✓ **[Step 2] Numerical Modeling:** Utilize Coastal KOOS (KIOST) data as ground truth (uvTS).
- ✓ **[Step 3] Number of Design sites:** (Existing observation network) + # of Design sites (1-4).
- ✓ **[Step 4] Optimization:** Multi-Objective Optimization (Weighted Sum Method & Brute-Force Optimizer, WSM-based BFO).
- ✓ **[Step 5] Optimal Array:** Extract the optimal array from Pareto-optimal solutions.
- ✓ **[Step 6] OSSEs:** Verify the effectiveness of data assimilation based on OSSEs (Observing System Simulation Experiments).
- ✓ **[Step 7] In-situ Validation:** Evaluate the necessity of each deployment site using results obtained from in-situ buoy installations at designated locations.

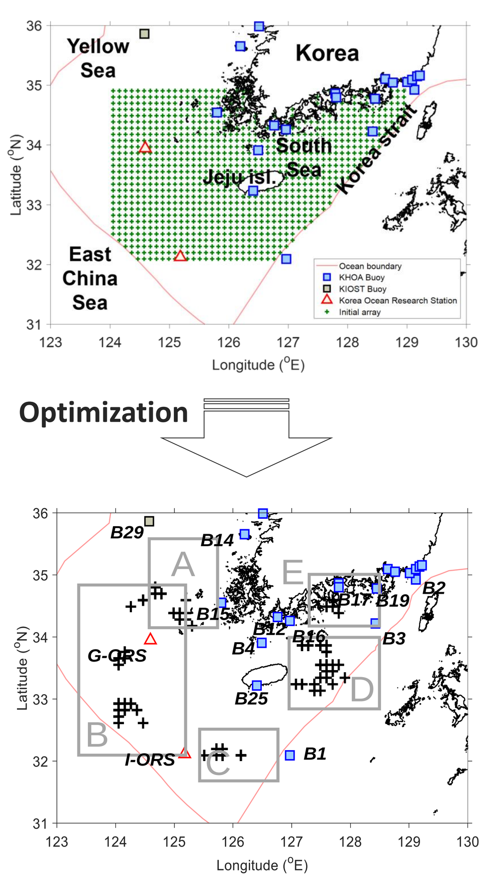



<Fig. 1. Study area and existing buoy observation network>

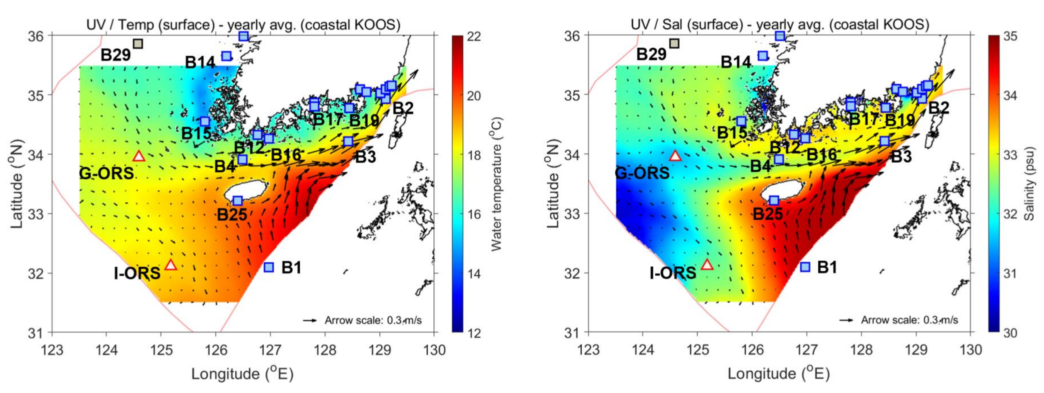



<Fig. 2. Procedure of design for buoy observation network>

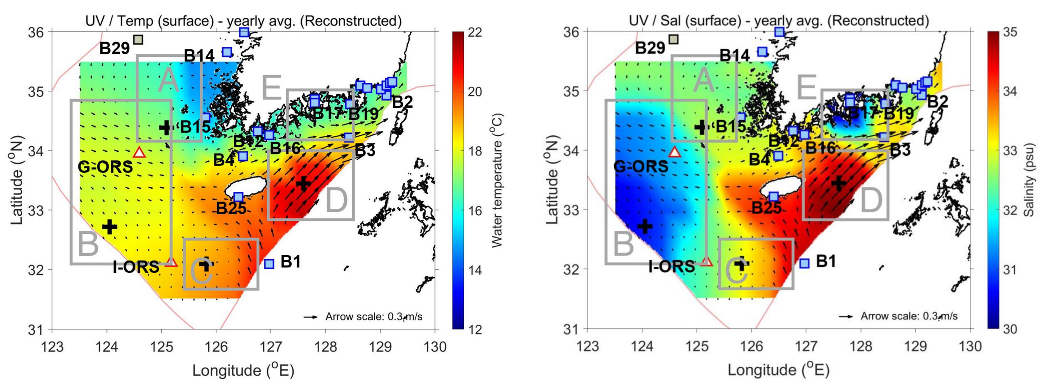
## Results and Discussion




<Fig. 3. (upper) Initial array of candidate sites and (lower) optimal sites>

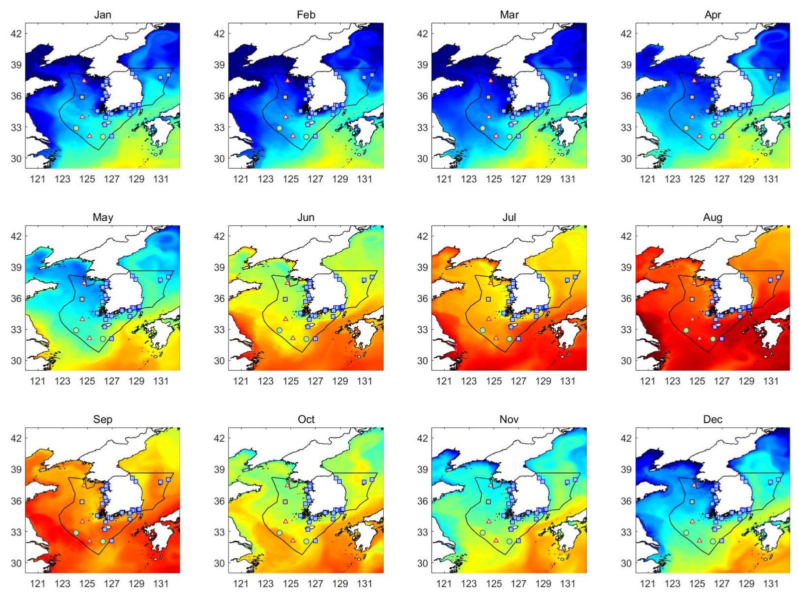


<Fig. 4. Spatial distribution of ground-truth (left: water temperature & current; right: salinity + current)

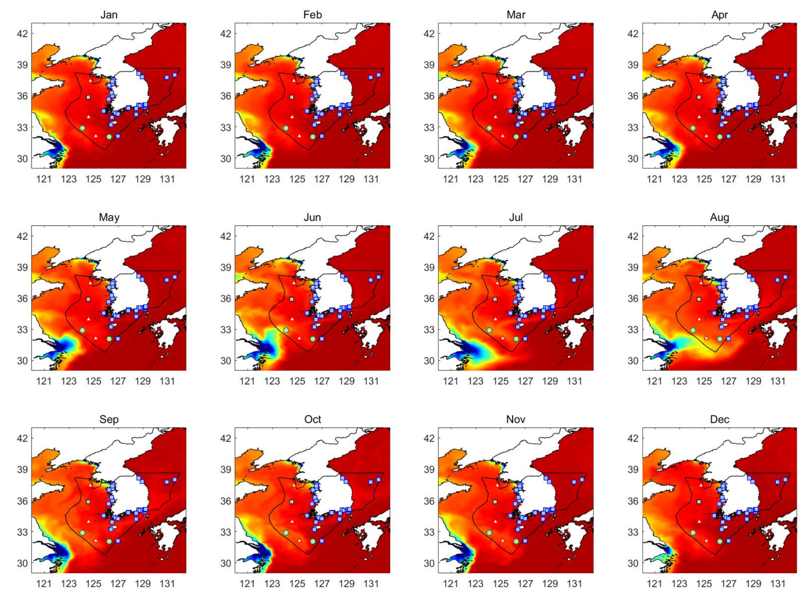


<Fig. 5. Spatial distribution constructed by existing observation network and optimal sites ($n_b$=4) which is weighted by water temperature>

- ✓ **[Region A]** Temperature cold bias : Summer cold-water mass (upwelling) in the southwestern coast of Korea
- ✓ **[Region B]** Salinity cold bias – Low-salinity front due to CDW (Changjiang Diluted Water front)
- ✓ **[Region C]** Current bias – Boundary of the East China Sea (tide dominant) and TWC (Tsushima Warm Current (northeastward current dominant)
- ✓ **[Region D]** Current, temperature, salinity – Northeastward current and thermohaline front of the TWC
- ✓ **[Region E]** Salinity cold bias – Low-salinity front caused by freshwater outflow from Gwangyang and Jinju Bays

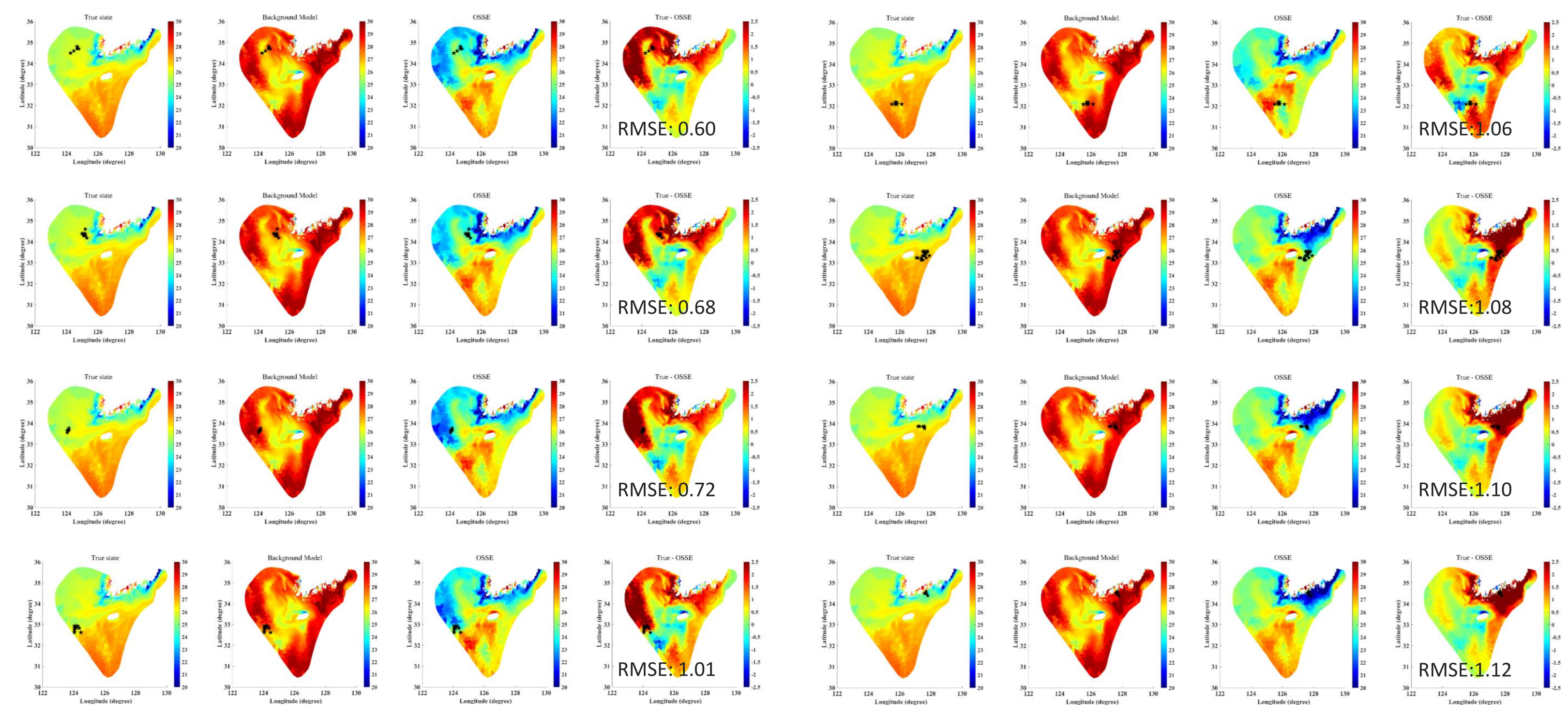


<Fig. 6. Monthly averaged spatial distribution of water temperature for ground-truth (KOOS)>



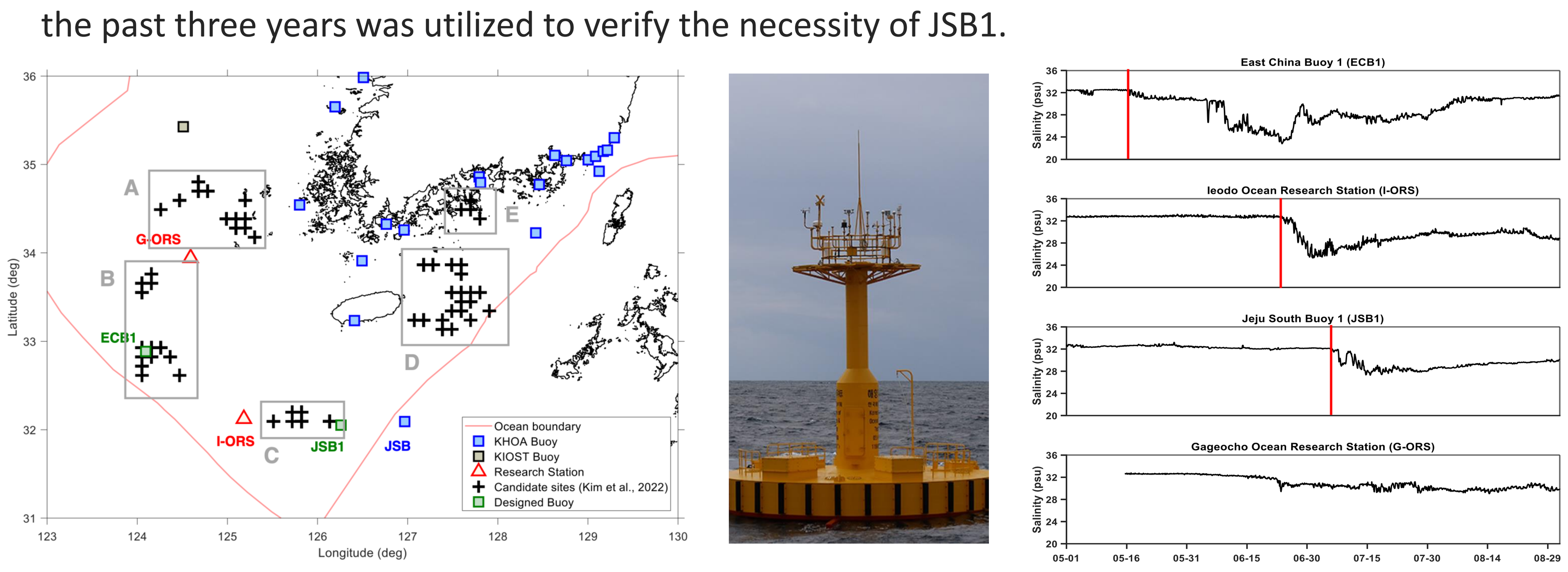
<Fig. 7. Monthly averaged spatial distribution of salinity for ground-truth (KOOS)>

- ✓ The OSSEs were conducted to evaluate the performance of the designed observation network in capturing the spatiotemporal variability of oceanographic parameters.
- ✓ The OSSEs framework incorporated a realistic ocean circulation model and synthetic observations to simulate the data assimilation process (True → Synthetic obs. → DA to Control)
- ✓ Higher RMSE indicates greater dependence on observations, while lower RMSE suggests a decreased necessity for observations.

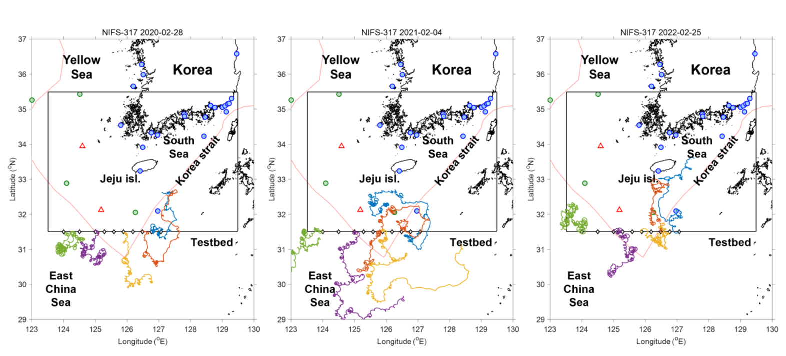



<Fig. 8. Spatial distribution of water temperature for validation of data assimilation effects for each candidate group determined through optimization>

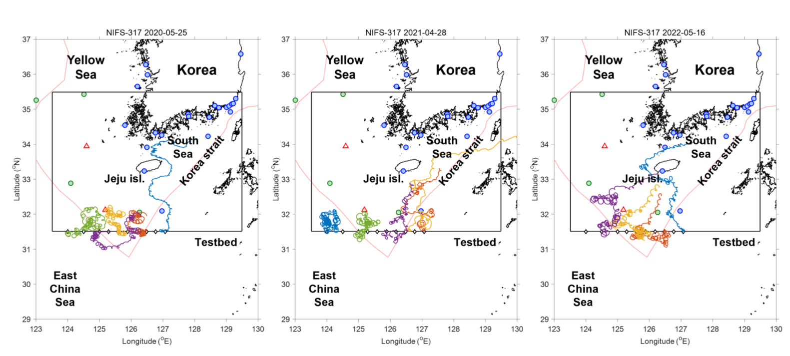
- ✓ During the decision-making process, two priority installation areas (Regions B & C) were selected, and ocean observation buoys were deployed in the field (East China Sea 1 - ECB1, South of Jeju 1 - JSB1) to collect and analyze observational data from 2022 to verify the necessity of the deployment sites.
- ✓ **[East China Sea 1]** Deployed in Region B for proactive observation of the low-salinity front caused by the CDW. The necessity of ECB1 was verified by comparing the salinity data collected from IORS, GORS and another newly deployed buoy (JSB1).
- ✓ **[South of Jeju 1]** Deployed in Region C to monitor the boundary area between the East China Sea and the TWC, where tidal currents and the northeastward current of the TWC are predominant. Due to observation errors in current data from JSB1, surface drifter data deployed by KIOST over the past three years was utilized to verify the necessity of JSB1.



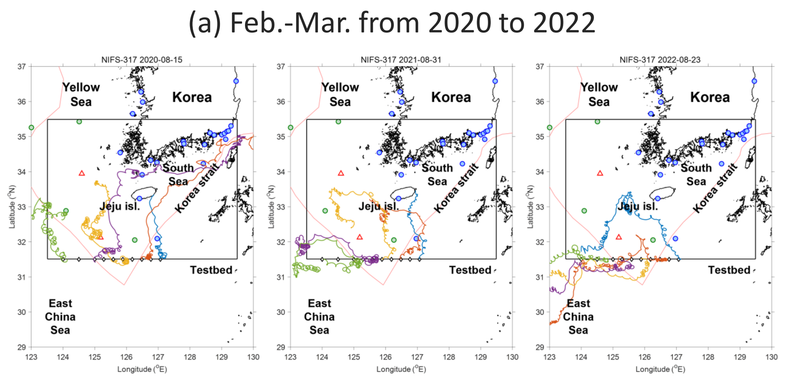

<Fig. 9. (left) Candidate sites proposed by Kim et al. (2022) (black +) and deployed buoy locations (green circle), (middle) image of the deployed buoy, and (right) time-series of salinity at ECB1, IORS, JSB1, and GORS>



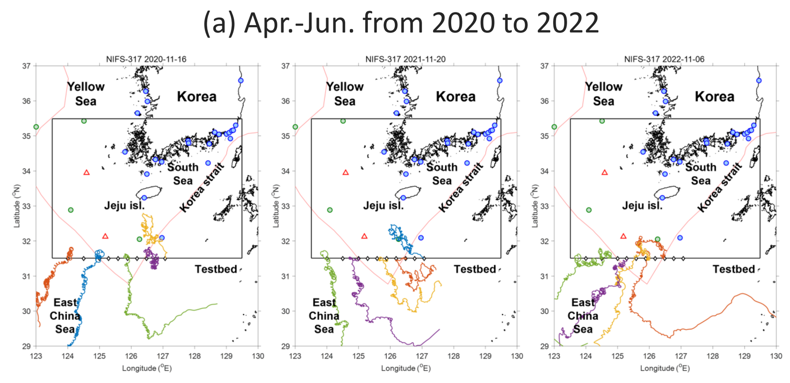
(a) Feb.-Mar. from 2020 to 2022



(a) Apr.-Jun. from 2020 to 2022



(a) Aug. – Sep. from 2020 to 2022



(a) Nov. – Dec. from 2020 to 2022

<Fig. 10. Trajectories of surface drifters deployed along line 317 by the National Institute of Fisheries Science (NIFS) from 2020 to 2022>

## Conclusions

- ✓ This study provides valuable insights into the practical design strategy and validation of ocean buoy observation networks using optimization, OSSEs, and real-time data collection, contributing to the design of effective ocean observation systems.
- ✓ There are plans to obtain valuable oceanographic information in the study area, which serves as a gateway to Korea's territorial waters, through further expansion of the observation network and data assimilation in Korea Operational Oceanographic System (KOOS)