KOOS
Korea Operational Oceanographic System

Introduction to Korea Operational Oceanographic System (KOOS)

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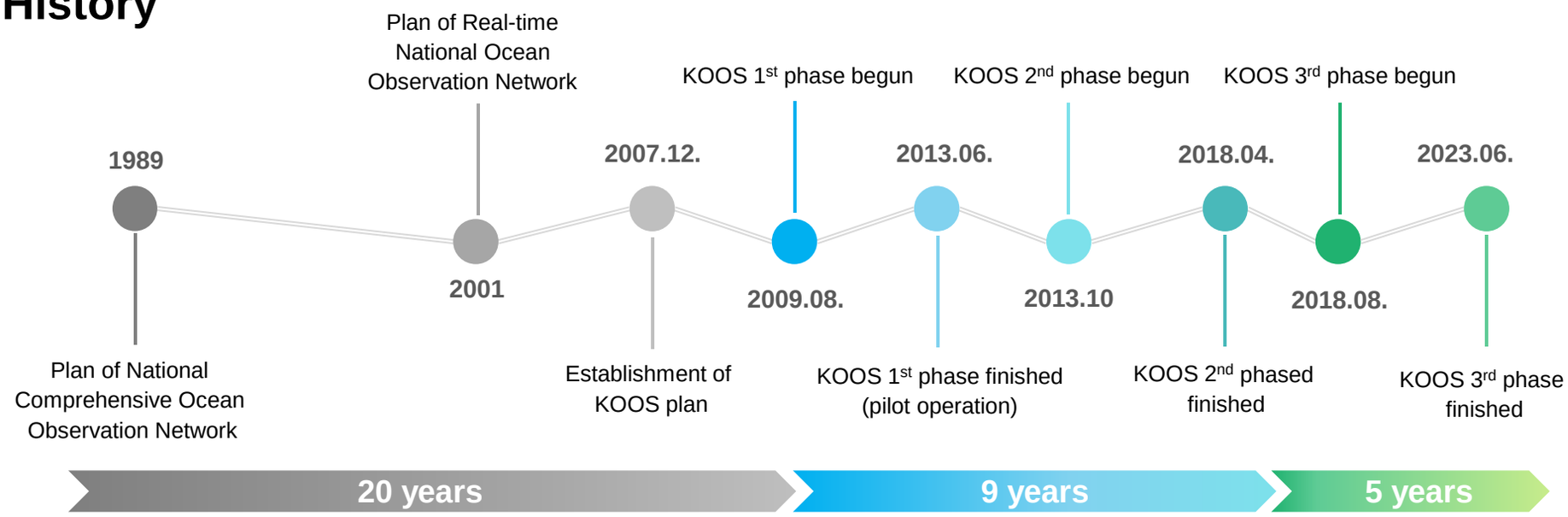
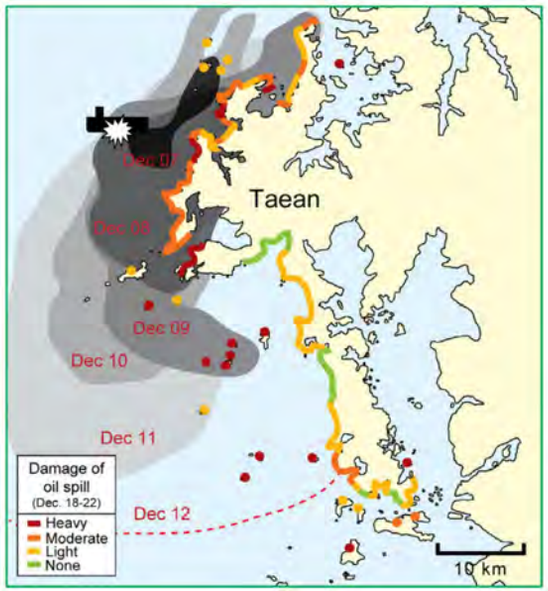
Introduction – Necessity and Background

History





***Heibei spirit* oil spill**

- ✓ Dec. 7, 2007
- ✓ 12,547 kℓ crude oil spilled
- ✓ 458 million USD in disaster damage

Image source : (left) Yim et al. (2012) / (right) Hong et al. (2014)

Introduction – Necessity and Background

MV Sewol-Ferry sinking accident (2014.04.16)

- 299 people dead, 5 missing, and 1,533 million USD damage
- The need for long-term prediction system for the search of missing persons arose due to the limitations of the existing system
- High-resolution prediction system needed
- Issues raised regarding the reliability of the data
  - Extension of the forecast from 3 days to 7 days
  - Establishment of an unstructured grid prediction system
  - Development of a standard for evaluating forecasting accuracy

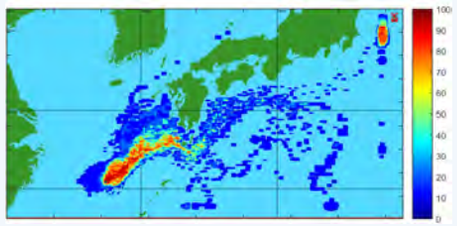
MV Stella Daisy sinking accident (2017.03.31)

- 22 people missing, including 8 Koreans

- Global marine meteorological and ocean circulation prediction system are needed for rapid SAR support in the event of maritime accidents abroad (dependent on foreign data)
  - Establish the global marine meteorological and ocean circulation prediction system

Oil spill accident

- *Sanchi* collision (2018.01.06)
  - 32 people dead, 153,200 kℓ of condensate oil spilled



Spilled oil advection and diffusion prediction results

- Wu Yi San collision (2014.01.31)
  - 899 kℓ of crude oil spilled, contaminating 407 hectares
  - High-resolution prediction system is needed in the event of a coastal accident
    - Establishment of an unstructured grid prediction system

Typhoon Hinnamnor approaching (2022.09.06)

- 14 people dead, 3 injured, 2 missing, and 597 million USD damage
- It is necessary to consider the interaction of waves during typhoons and other severe weather conditions
  - Establishment of an atmosphere-ocean-wave coupled prediction system

KOOS

Korea Operational Oceanographic System

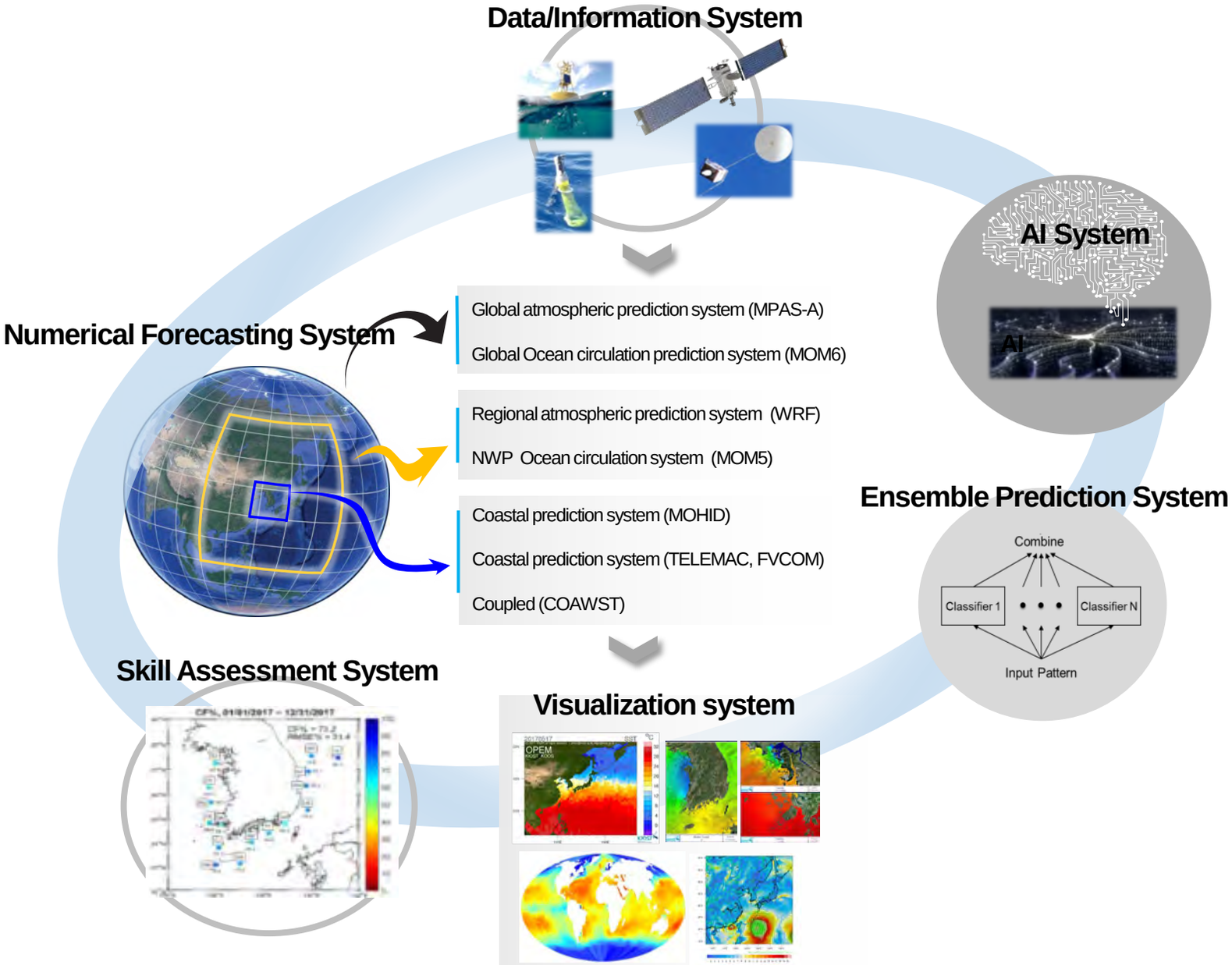
→ Provide the best solution for marine environmental issues

Ocean Observation

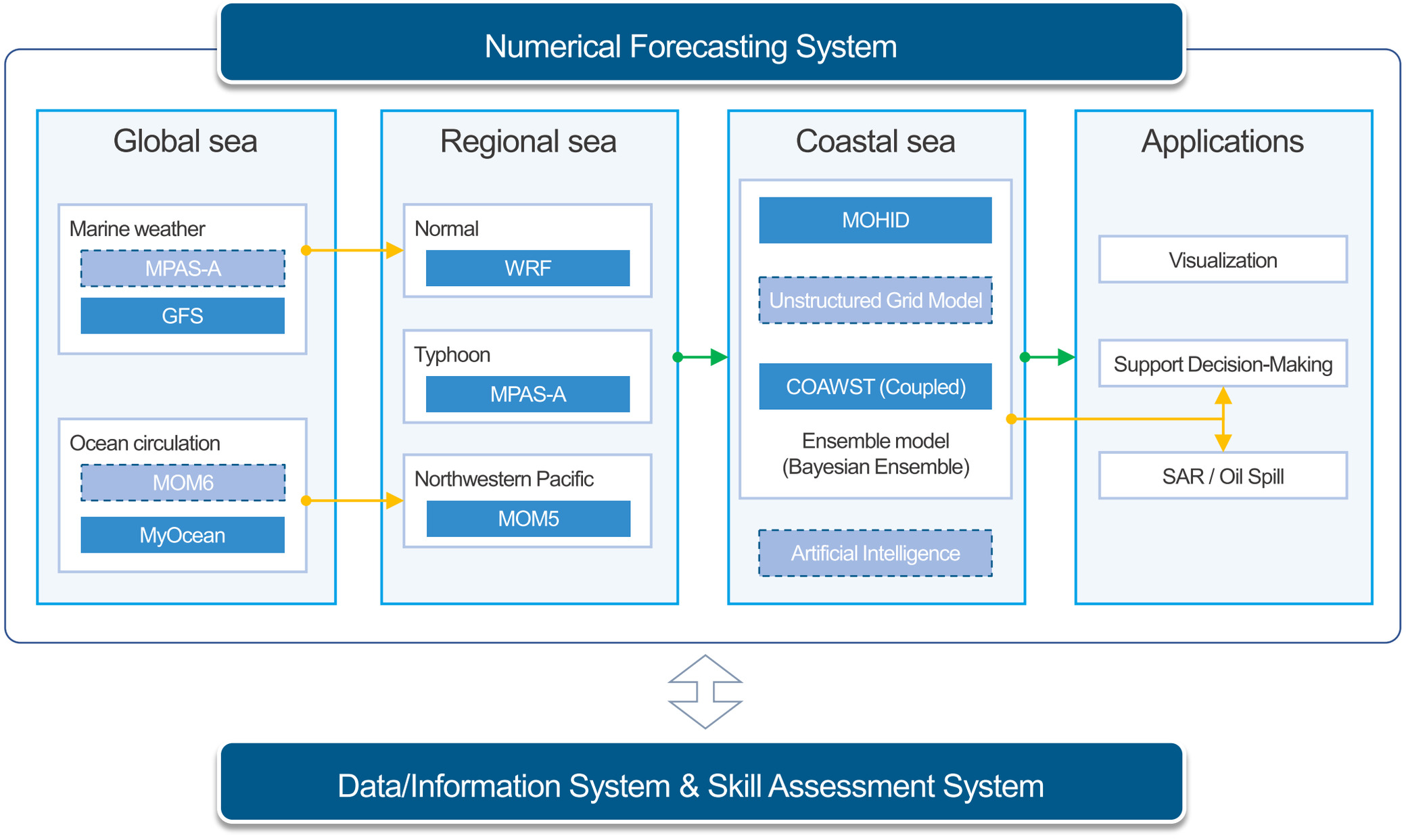
Numerical Models and Data Management

Ocean Information Service and Applications

KOOS


Data/Information System
Numerical Forecasting System
Global atmospheric prediction system (MPAS-A)
Global Ocean circulation prediction system (MOM6)
Regional atmospheric prediction system (WRF)
NWP Ocean circulation system (MOM5)
Coastal prediction system (MOHID)
Coastal prediction system (TELEMAC, FVCOM)
Coupled (COAWST)
AI System
AI
Ensemble Prediction System
Combine
Classifier 1
Classifier N
Input Pattern
Skill Assessment System
Visualization system

KOOS


Numerical Forecasting System
Global sea
Marine weather
MPAS-A
GFS
Ocean circulation
MOM6
MyOcean
Regional sea
Normal
WRF
Typhoon
MPAS-A
Northwestern Pacific
MOM5
Coastal sea
MOHID
Unstructured Grid Model
COAWST (Coupled)
Ensemble model
(Bayesian Ensemble)
Artificial Intelligence
Applications
Visualization
Support Decision-Making
SAR / Oil Spill
Data/Information System & Skill Assessment System

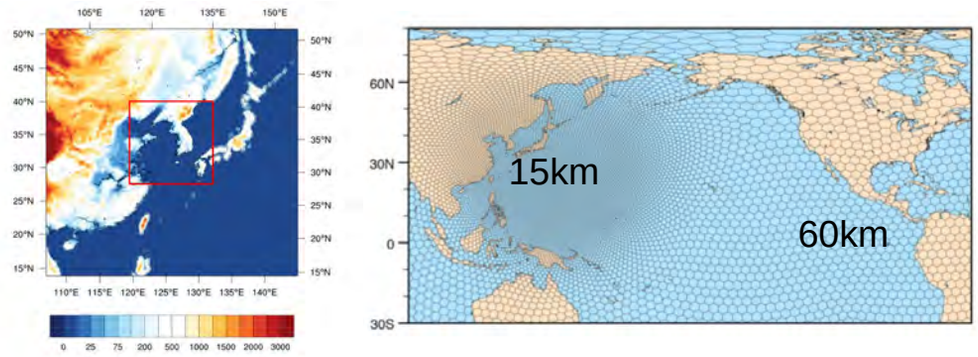
	Model		Domain	Horiz. Resol. (No.)	Vertical Layer	DA		I.C./B.C.	Bathymetry	Production freq.	Products	Pred. Time (interval)
						Scheme	Data					
Atmos.	MPAS-A (Global)		Global	60-15 km	60	EnKF, LETKF	Satellite, Observations, GTS	NCEP FNL	-	1 / day	wind, temp., press., and etc. (70)	1week (3H)
	WRF v4.1	D01	104.6~150.4°E 14.9~52.5°N	20 km (218×218)	60	3DVAR, 4DVAR	GTS, KMA buoy, ASCAT	MPAS-A NCEP GFS	-	2 / day	wind, temp., press., and etc. (16)	1week (1H)
		D02	121.1~133.6°E 29.N~39.6°N	4 km (361×361)								
Ocean Circulation	MOM5 (Regional, NWP)		98.9 ~ 170°E 5.0 ~ 63.0°N	1/24° (1704×1392)	51 (cartesian)	EnOI	NOAA OI SST GHRSST, Argo, GTSPP, KODC, RivDis	ECMWF, KMA MYOCEAN,	GEBCO + Korbathy (1/120°)	1 / week	temp., sal., current, elevation, etc.	10day (1day)
	MOM6 (Global)		Global	1/12° (4320×2160)	51 (Zstar+Isopycnal Hybrid)	EnOI	NOAA OI SST GHRSST, Argo, GTSPP, KODC, RivDis	WOA, KMA	GEBCO + Korbathy (1/120°)	1 / week		10day (1day)
	MOHID (Coastal)	L3	124.12~130.33°E 32.50~38.67°N	2 km (285×297)	40 (cartesian + sigma)	-	-	WRF, HYCOM/MOM5, FES2012	KHOA nautical chart + Korbathy (1/120°) + water depth (obs.)	1 / day		1week (1H)
		L4	124.50~130.13°E 32.92~38.54°N	300 m (1620×1620)								
Unstructure Grid	TELEMAC (Coastal)	M	117.55~142.25°E 23.87~51.96°N	6 km - 100 m (451,806 × 36 node)	36	-	-	WRF, HYCOM/MOM5, FES2014	GEBCO + KHOA nautical chart + Korbathy (1/120°) + water depth (obs.)	1 / day	temp., sal., current, elevation, etc.	1week (1H)
		K	124.24~130.39°E 32.65~39.09°N	3 km - 50 m (330,662×36 node)				WRF, MOHID L3 results				
	FVCOM	C1	□□□	5km - 10 m (61,710 node)	40 (sigma)	OI	NOAA OI SST	MOHID/HYCOM, WRF	GEBCO + Korbathy (1/120°) + BADA v1	1 / day	temp., sal., current, elevation, etc.	3day (1H)
		C2	□□□□	5km - 10 m (81,852 node)								
Coupled	COAWST (ROMS-WRF-WW3)		126~129.4°E 33.3~35.2°N (□□)	Ocean 1km (328X218), Atmos. 1-5km (150X100), Wave 1km (328X218)	Ocean: 20 Atmos.: 32 Wave: 1	EnOI	GTS, KMA buoy, ASCAT, OISST, AVISO	NCEP GFS, HYCOM	ETOPO1 (1/60°)	1 / day	Atmos.: Wind, temp., press., and etc. (16) Ocean: current, elevation, temp., sal., wave	4 day (1H)
			126.5~142°E 33.4 ~ 52°N (□□)	Ocean 2km (634X1035), Atmos. 20km (200X250), Wave 2km (634X1035)	Ocean: 41 Atmos.: 32 Wave: 1							
			125~125.9°E 35.2~38°N (□□)	Ocean 9km (309X171), Atmos. 9km (100X120), Wave 9km (309X171)	Ocean: 20 Atmos.: 30 Wave: 1							
			117~131.9°E 20.5~42°N (□□)	Ocean 2km (713X1196), Atmos. 6km (450X525), Wave 2km (713X1196)	Ocean: 41 Atmos.: 32 Wave: 1							
Wave	SWAN	L1	117.00~143.00°E 20.0~50.00°N	9 km (313×361)	1	-	-	WRF	KHOA nautical chart (detailed) + Korbathy (1/120°)	1 /day	wave height, wave direction, wave period, 2D wave spectrum	3day (1day)
		L2	124.00~133.02°E 32.00~39.02°N	2 km (346×351)								
		L3	124.50~130.13°E 32.92~38.54°N	300 m								

KOOS – Numerical Forecasting System (Weather)

Weather Forecasting System

		1st phase	2nd phase	3rd phase
Model		WRF ver. 3.1.	WRF ver. 3.7	MPAS-A
Domain		Regional	Regional	Global
Grid	20 km	163x217	218x218	60-15 km unstructured grid
	4 km	270x270	361x361	
Data assimilation		X	Cycling 3D-Var	EnKF LETKF

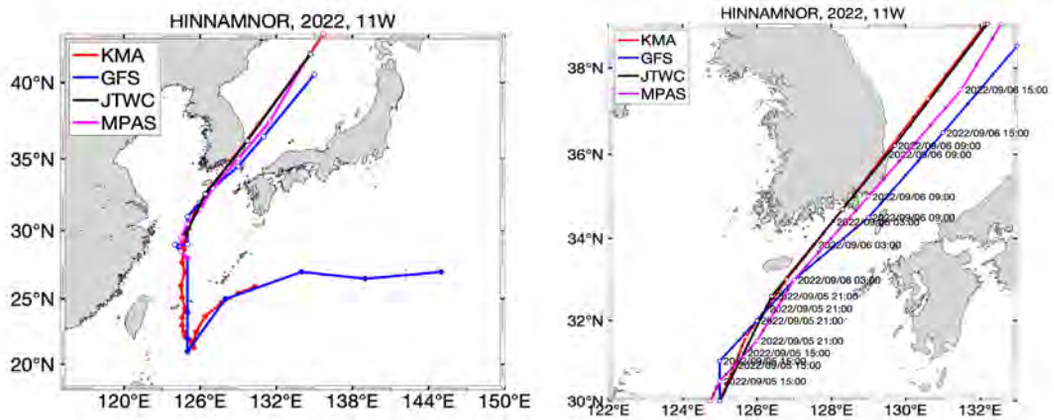
An efficient global unstructured grid model for the Northwest Pacific ocean



- Northwest Pacific ocean including the area from Korea to where typhoons originate : 15 km resolution

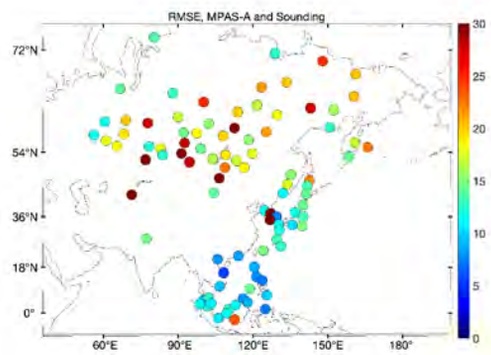
Evaluation of the Forecasting Accuracy

- Comparison of the prediction performance of Typhoon Hinnamnor in 2022

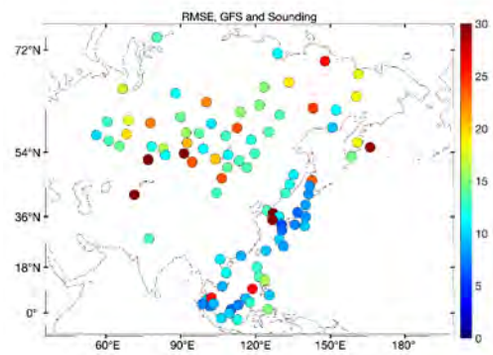


- 500 hPa geopotential height RMSE (gpm)

MPAS-A



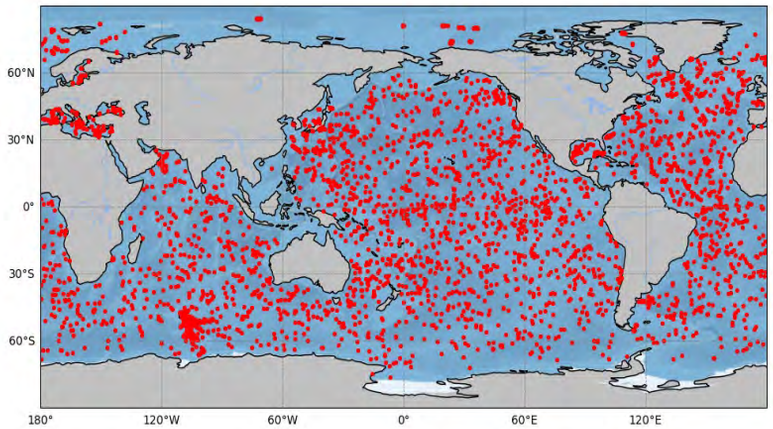
GFS



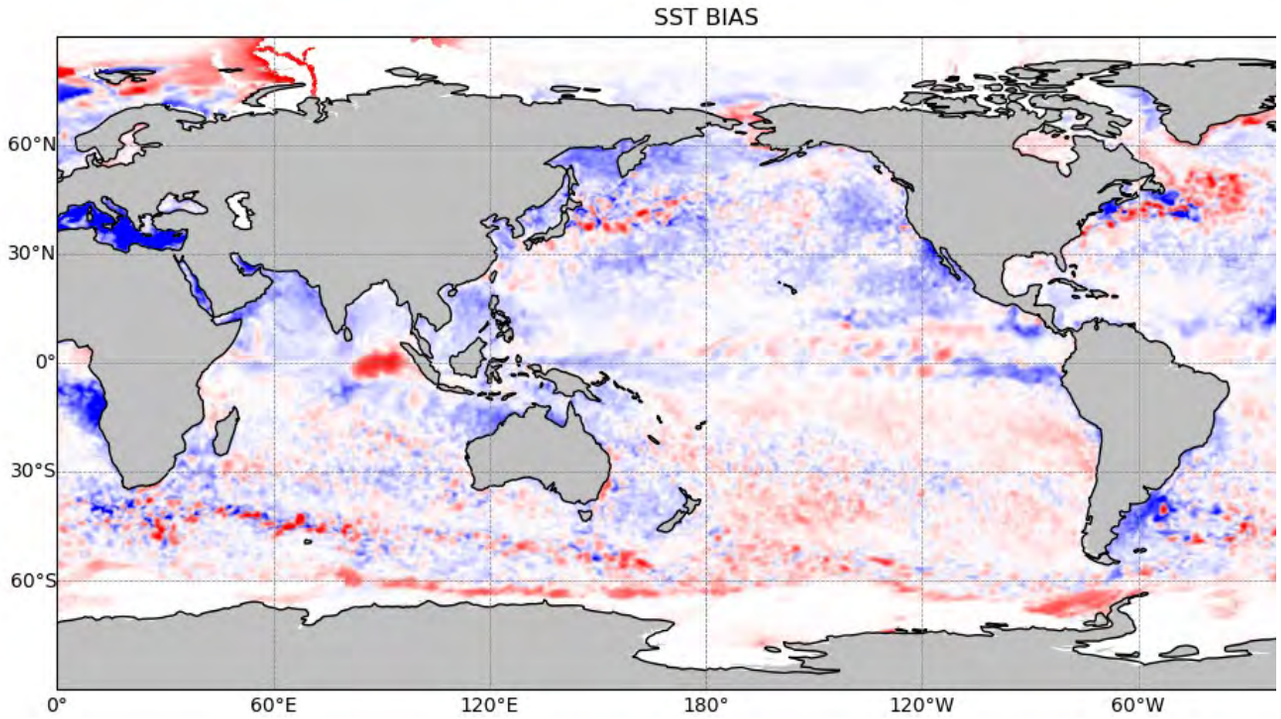
KOOS – Numerical Forecasting System (Ocean - Global)

KOOS-GlobalOPEM (Ocean Predictability Experiment for Marine environment)

- Model : GFDL-MOM6
- Domain : Global sea
- Resolution : 1/12° x 1/12° in horizontal (about 9 km) & 51 vertical layers (Hybrid-coordinate : zstart + isopycnal)
- Data assimilation : Ensemble Optimal Interpolation



- Sea surface temperature data is collected from OSTIA, and sea surface height data is collected from AVISO's along track data
- Temperature/salinity data are collected from the World Ocean Databased 2018 (WOD2018)

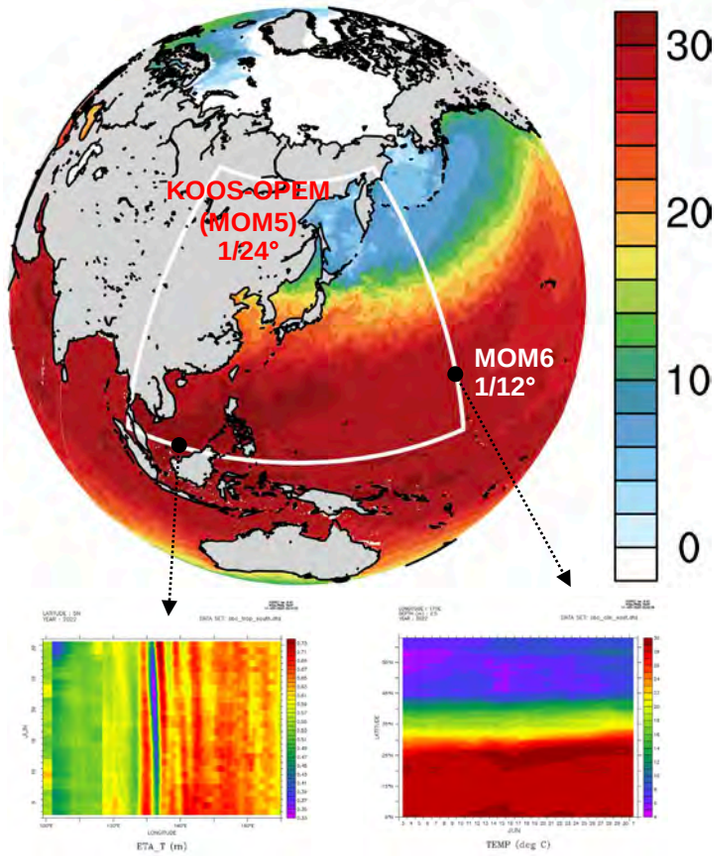


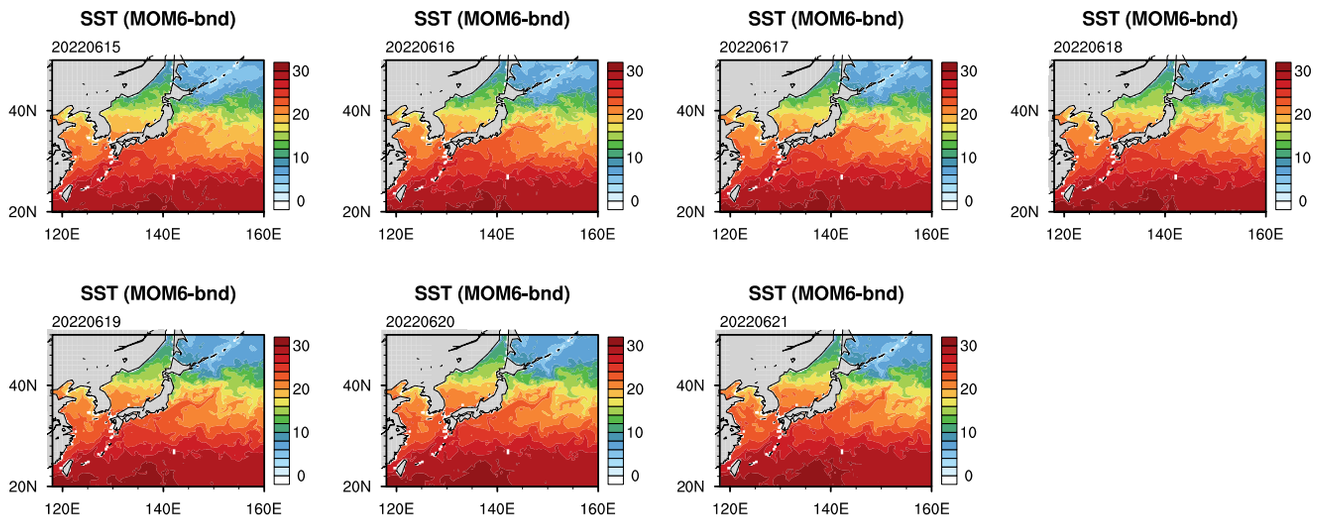
- Bias of sea surface temperature in the KOOS-GlobalOPEM pilot prediction field through comparison with OISST

KOOS – Numerical Forecasting System (Ocean - Regional)

KOOS-OPEM

- Model : GFDL-MOM5
- Domain : Regional sea (Northwestern Pacific Ocean)
- Resolution : 1/24° x 1/24° in horizontal (about 4 km) & 51 vertical layers (Hybrid-coordinate : zstart + isopycnal)
- Data assimilation : Ensemble Optimal Interpolation
- Running period : Total 24 days (DA : 14 days; Forecast : 10 days)



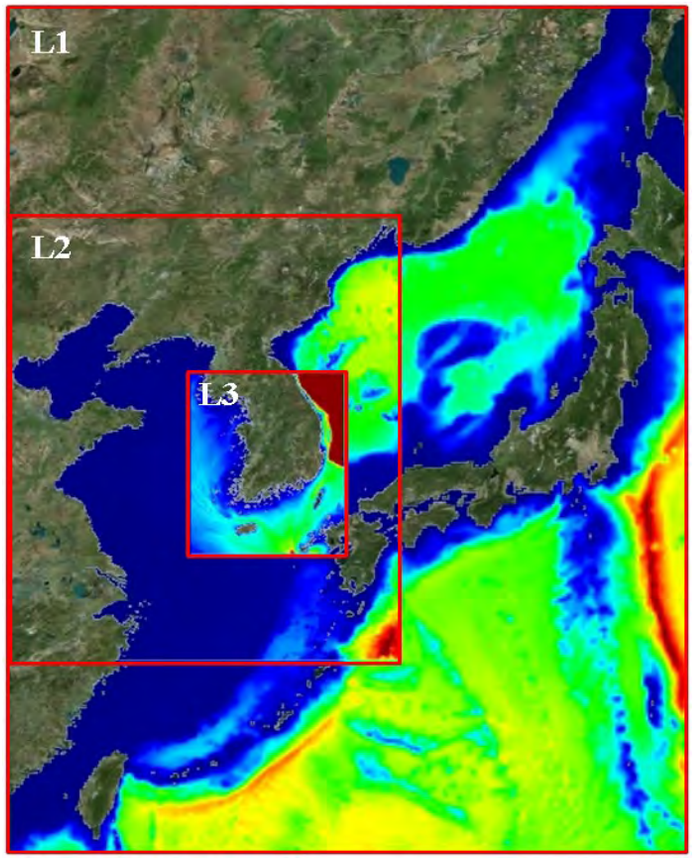


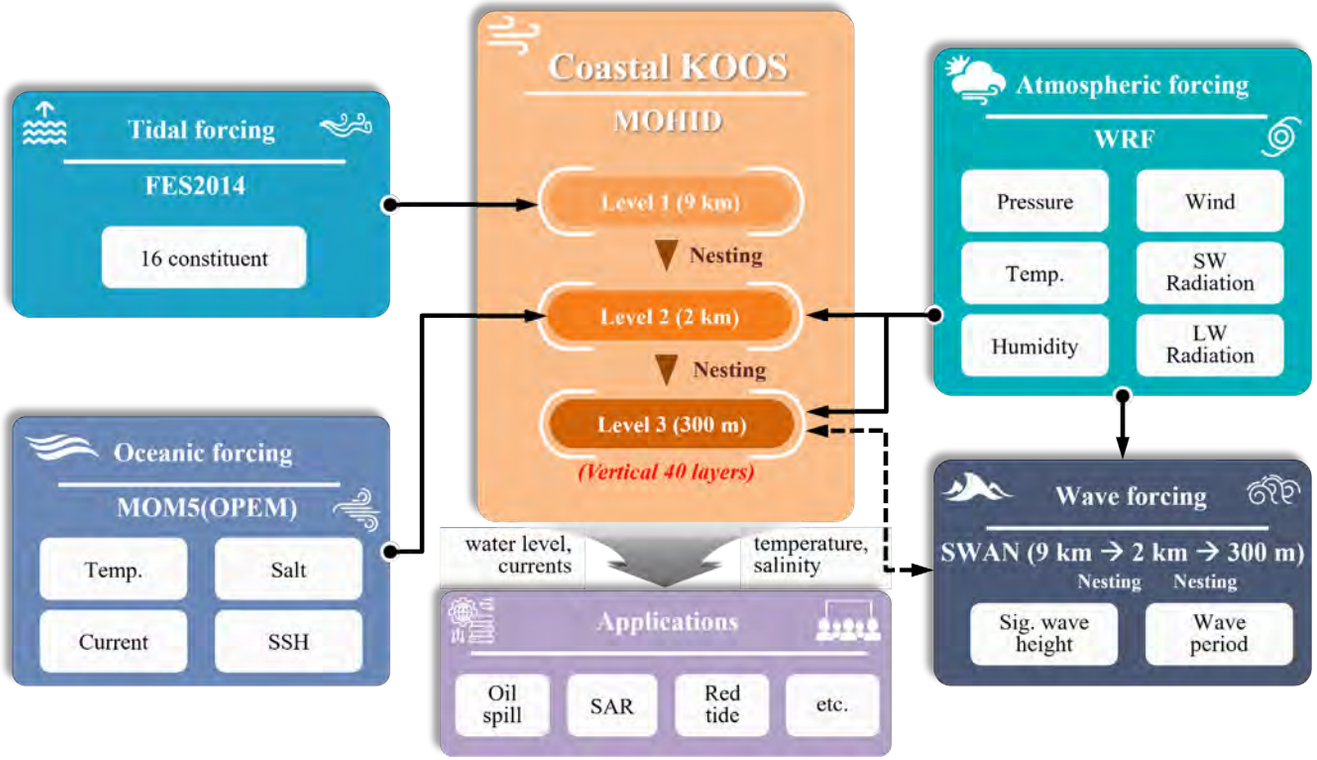
- The daily averaged 3-dimensional oceanographic variables (SSH, U, V, T, S) generated from the KOOS-GlobalOPEM are used to create input data for a regional model, which is assigned to the eastern and southern boundaries.
- Dynamic downscaling from KOOS-GlobalOPEM to KOOS-OPEM (1/12° to 1/24°) has been achieved, along with the integration of ocean data assimilation.

KOOS – Numerical Forecasting System (Coastal)

Coastal KOOS

- Model : MOHID
- Domain : Territorial seas of the Korean Peninsula
- Resolution : (L2) 1/48° x 1/48° (about 2 km) & (L4) 1/288°x1/288° (about 300 m) in horizontal & 40 vertical layers
- Running period : Forecast 7 days





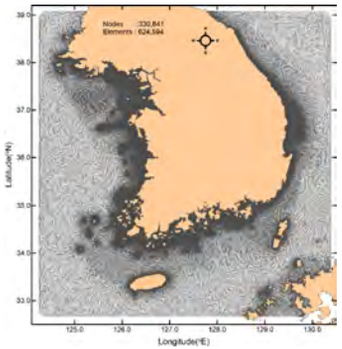
KOOS – Numerical Forecasting System (Coastal)

Unstructured Grid Model

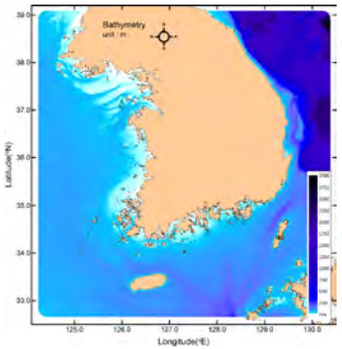
▶ Model : TELEMAC3D

A three-dimensional unstructured-grid-based coastal prediction system has been developed, utilizing ocean and meteorological prediction results from coastal KOOS as inputs.

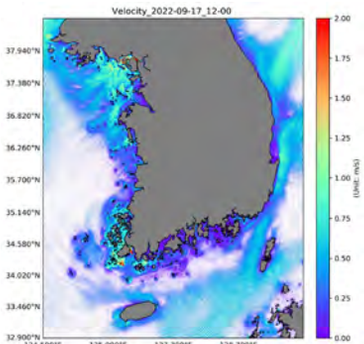
Grid



Bathymetry

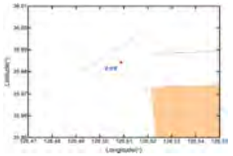


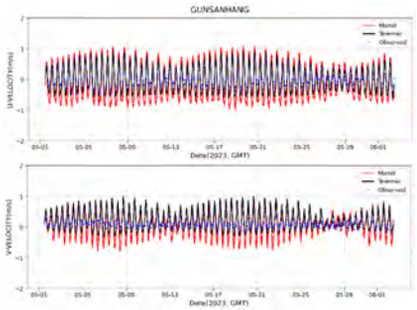
Forecasting results



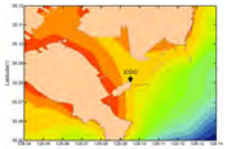
Comparison of surface current

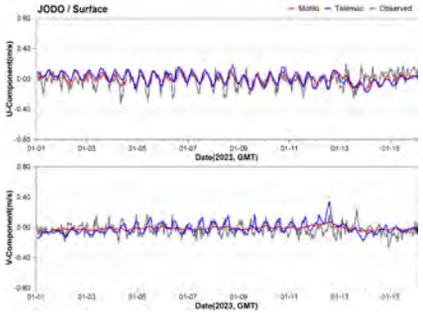
Gunsan





Jodo



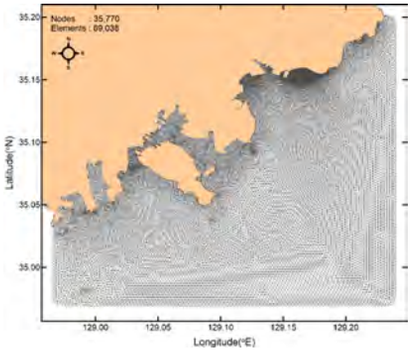


Unstructured Grid Model (Coupled)

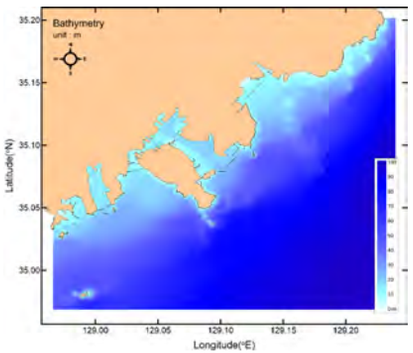
▶ Model : TELEMAC3D + TOMAWAC

A three-dimensional unstructured-grid-based coastal (shallow) prediction system has been developed by coupling with wave models, utilizing ocean and meteorological prediction results from coastal KOOS as inputs.

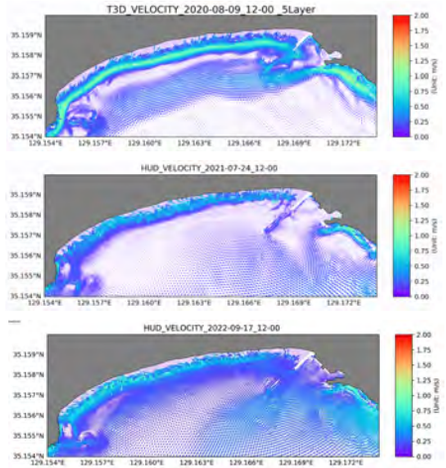
Grid

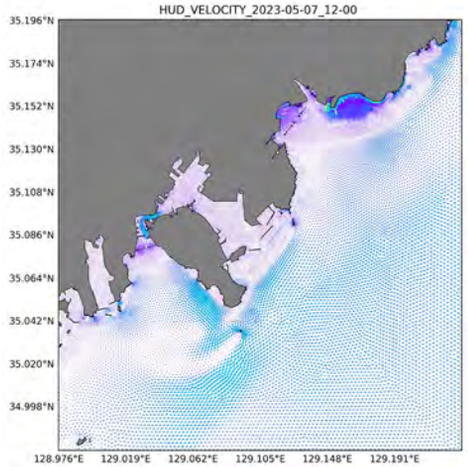


Bathymetry



Forecasting results



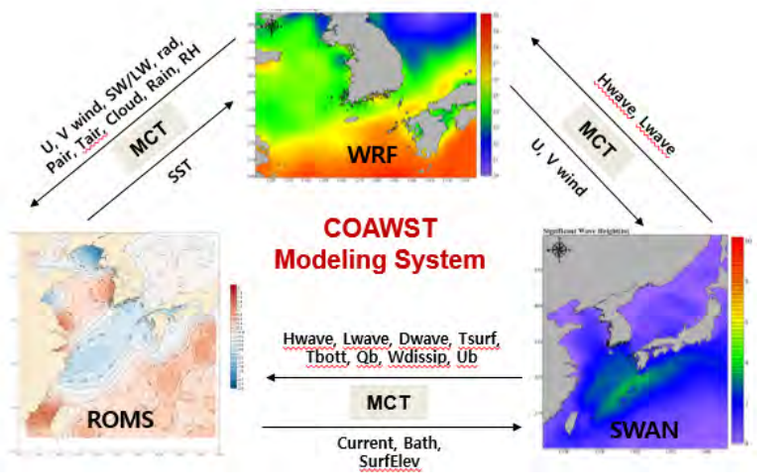


KOOS – Numerical Forecasting System (Coupled)

COAWST

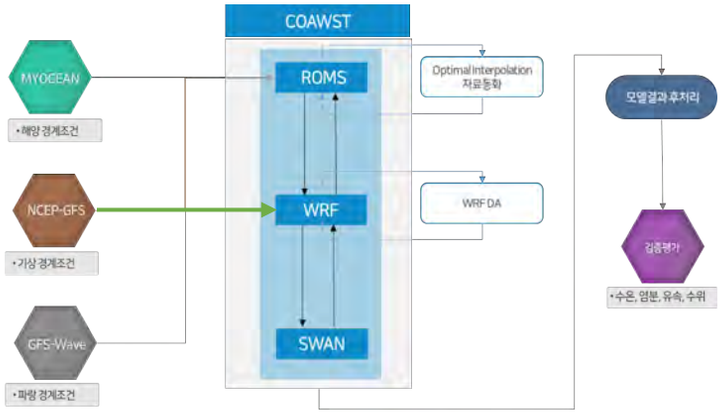
▶ Model : ROMS – WRF – SWAN

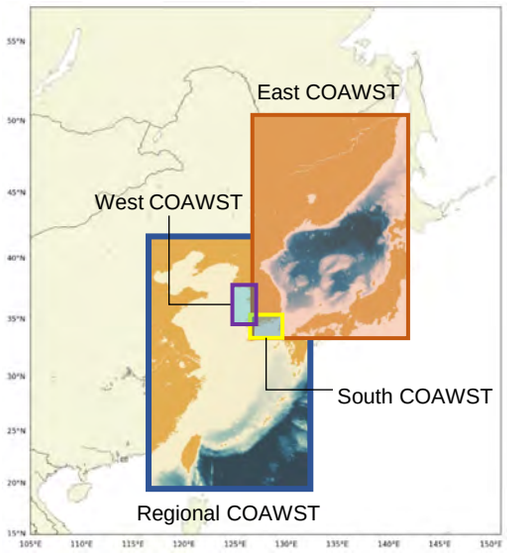
- The Model Coupling Toolkit (MCT) was utilized to apply a two-way coupling between each individual model

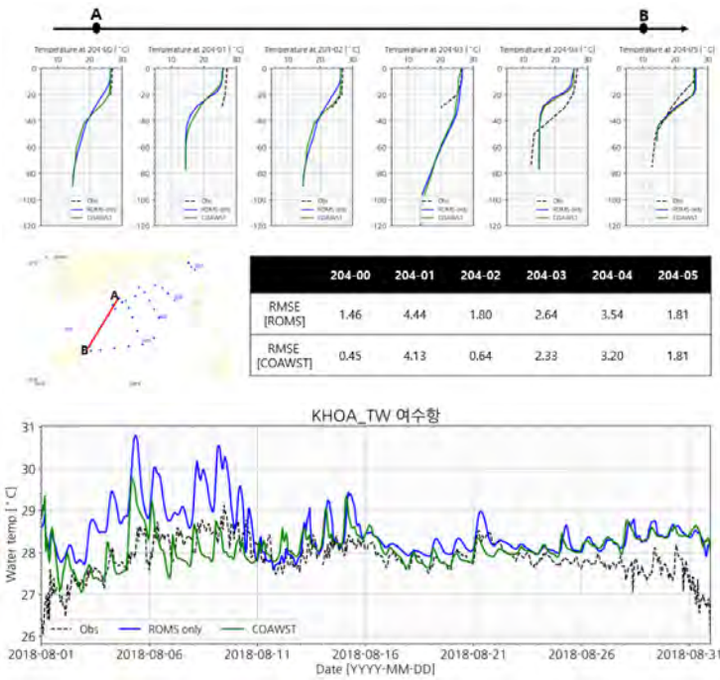


	Contents	Regional	West	South	East
ROMS	Resolution	2 km	3 km	1 km	2 km
	Vertical layer	41 layer	20 layer	20 layer	41 layer
	Lateral boundary	MYOCEAN / HYCOM			
	Vertical mixing	GLS	Mellor-Yamada	Mellor-Yamada	GLS
WRF	Resolution	6 km	9 km	1 km	10 km
	Vertical layer	32 layer	27 layer	32 layer	32 layer
	Lateral boundary	NCEP – GFS			
SWAN	Resolution	2 km	9 km	1 km	2 km
	Lateral boundary	WW3 Global			

COAWST Operational system configuration

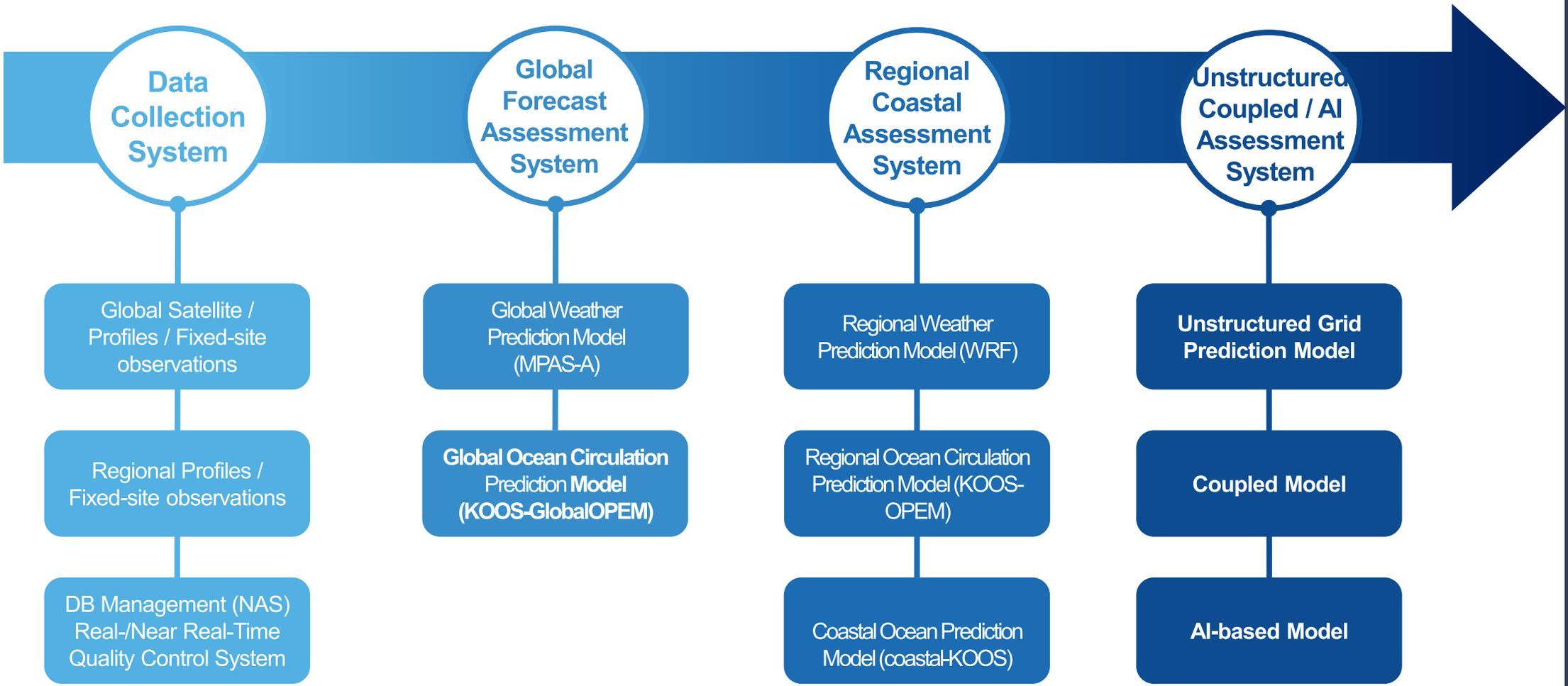






	204-00	204-01	204-02	204-03	204-04	204-05
RMSE [ROMS]	1.46	4.44	1.80	2.64	3.54	1.81
RMSE [COAWST]	0.45	4.13	0.64	2.33	3.20	1.81

KOOS – Data/Information System



KOOS – Skill Assessment System

Evaluation of the forecasting accuracy

- CF : 78.8 → 82.2% (+3.4%)
- SS : 80.2 → 85.0% (+4.8%)

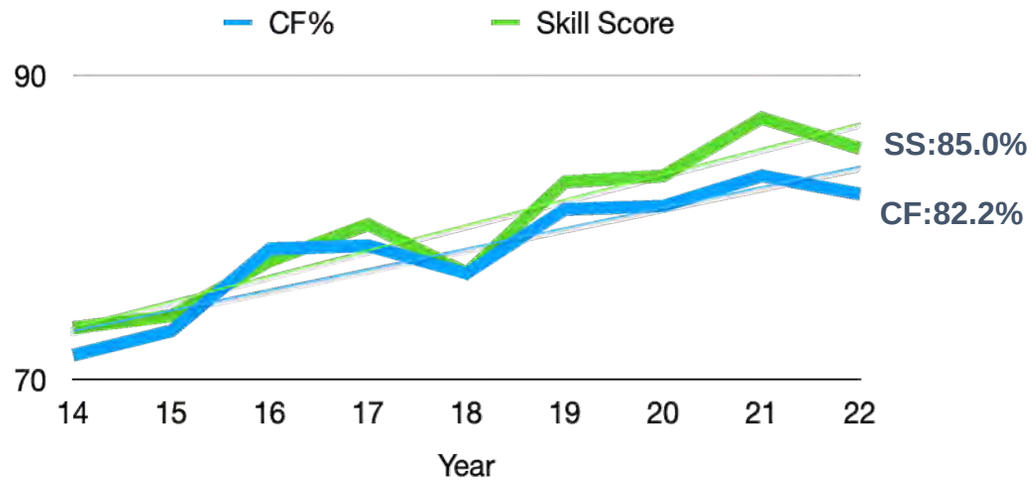
$$CF = \frac{\text{days that meet the target criteria}}{\text{days of forecast}} \times 100$$

$$SS = \frac{MSE\text{-}MSE_{clim}}{MSE_{perfect}\text{-}MSE_{clim}} = 1 - \frac{MSE}{MSE_{clim}}$$

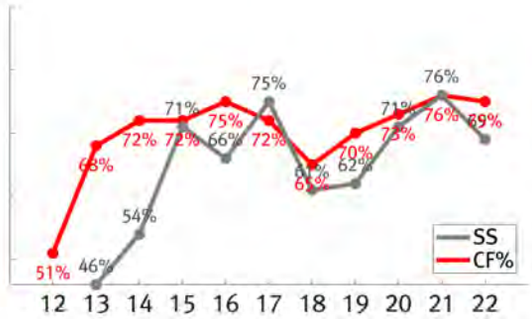
Variables	Statistics	Target criteria
wind speed (m/s)	RMSE%	40%
sea level (m)	Correlation	0.9
current speed (m/s)	RMSE	0.2 m/s
wave height (m)	RMSE%	40%
temperature (℃)	RMSE	1.5℃
salinity (psu)	RMSE	0.2 psu

	Wind	Wave	SST	Sea level	Current	Avg.
CF %	86	75	79	99	72	**82.2**
SS (CC)	85	69	94	95	82	**85.0**

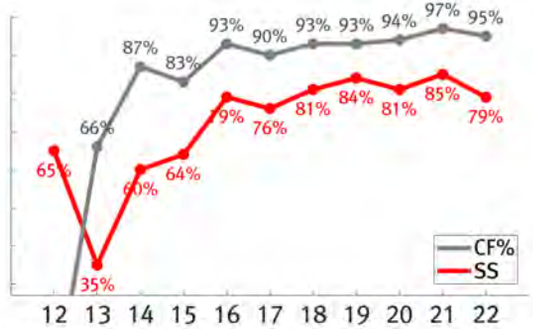
CF: Central Frequency; SS: Skill Score



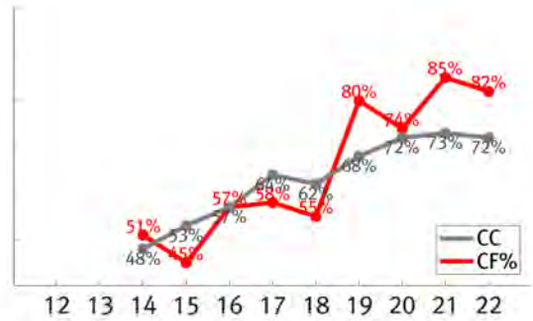
Wave height



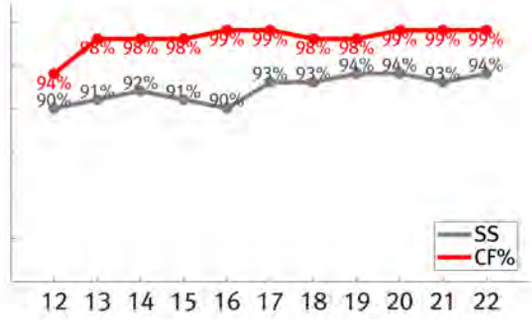
Water temperature



Current speed

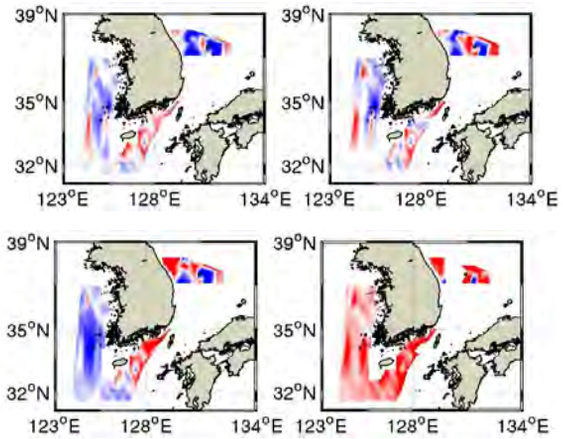


Sea level

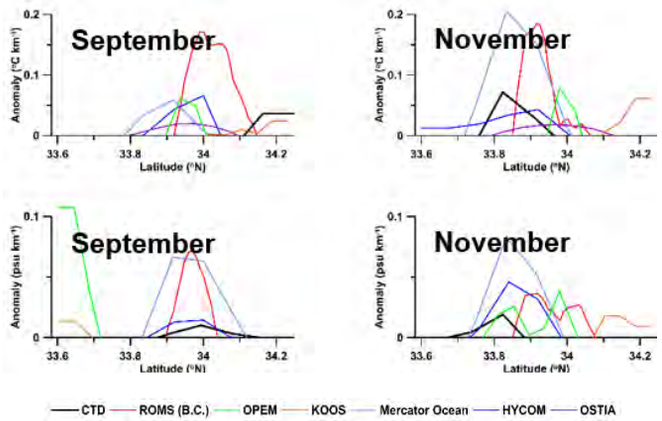


KOOS – Skill Assessment System

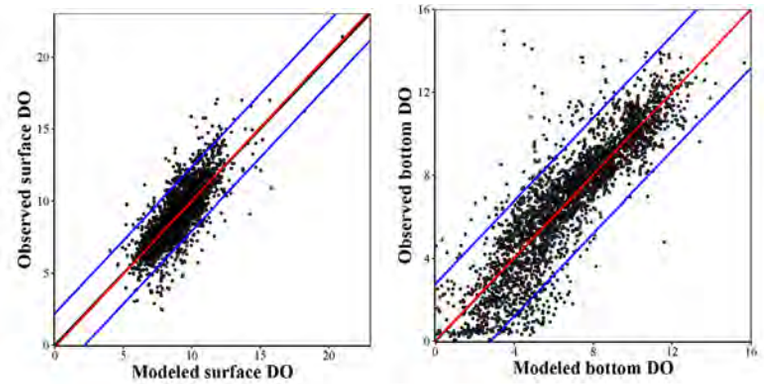
Mixing Layer



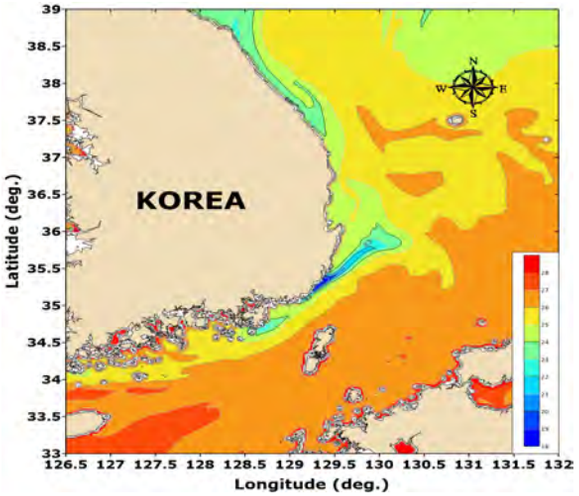
Thermohaline front (South)



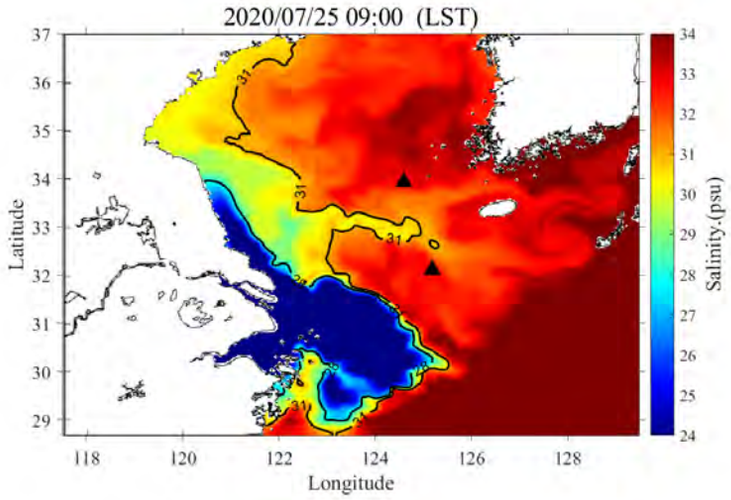
Hypoxia water mass



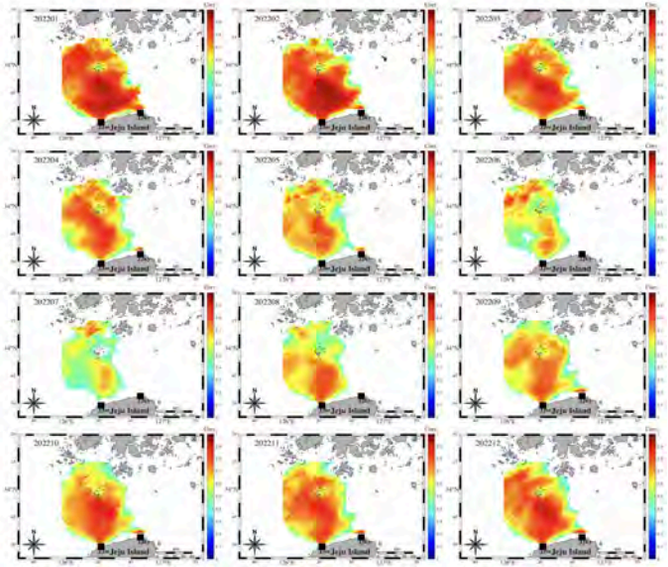
Cold water upwelling (East)



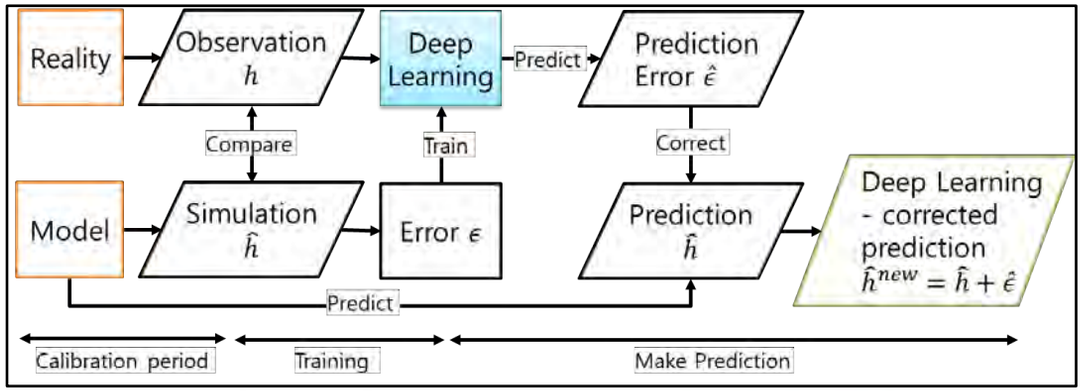
Low-salinity water (ECS)

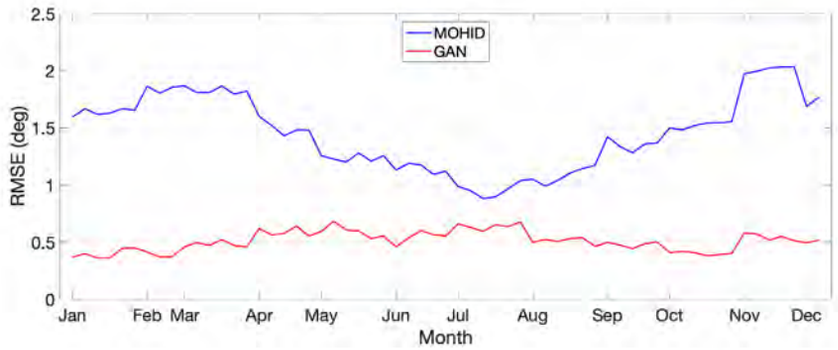


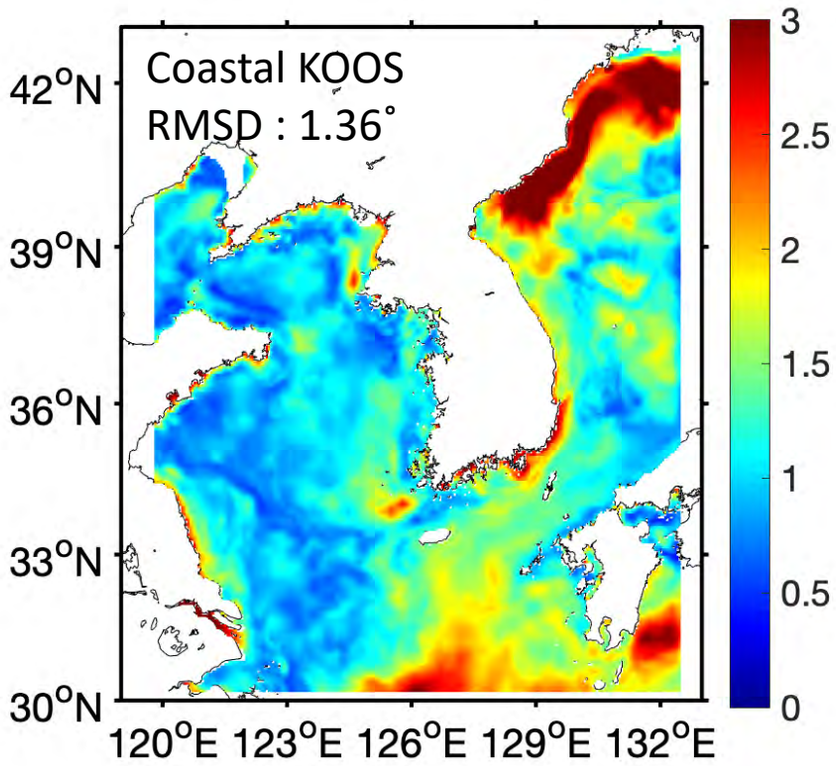
Surface current (North & South Jeju)

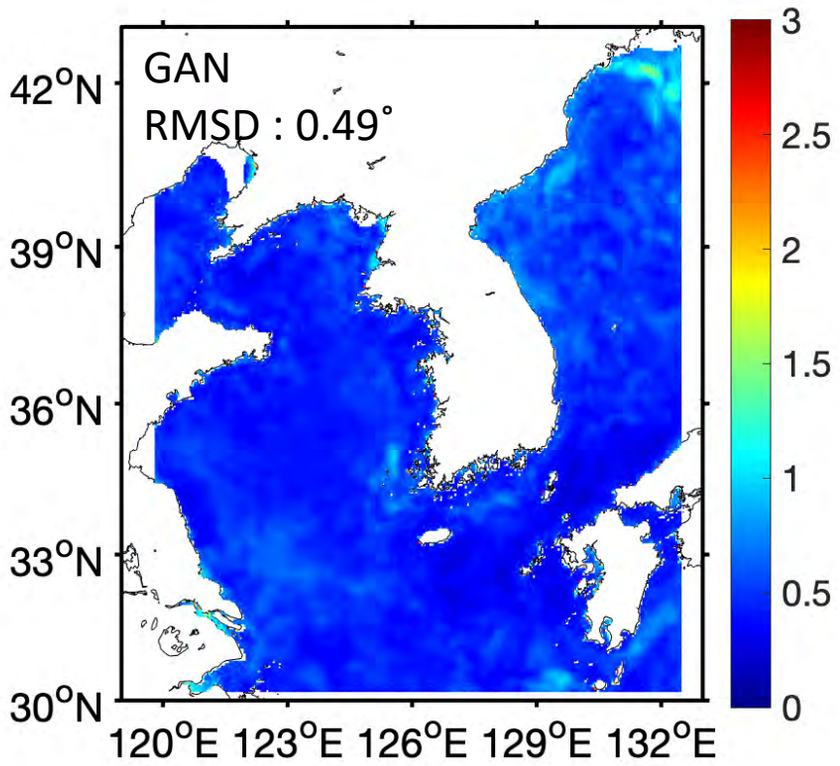


KOOS – Artificial Intelligence System

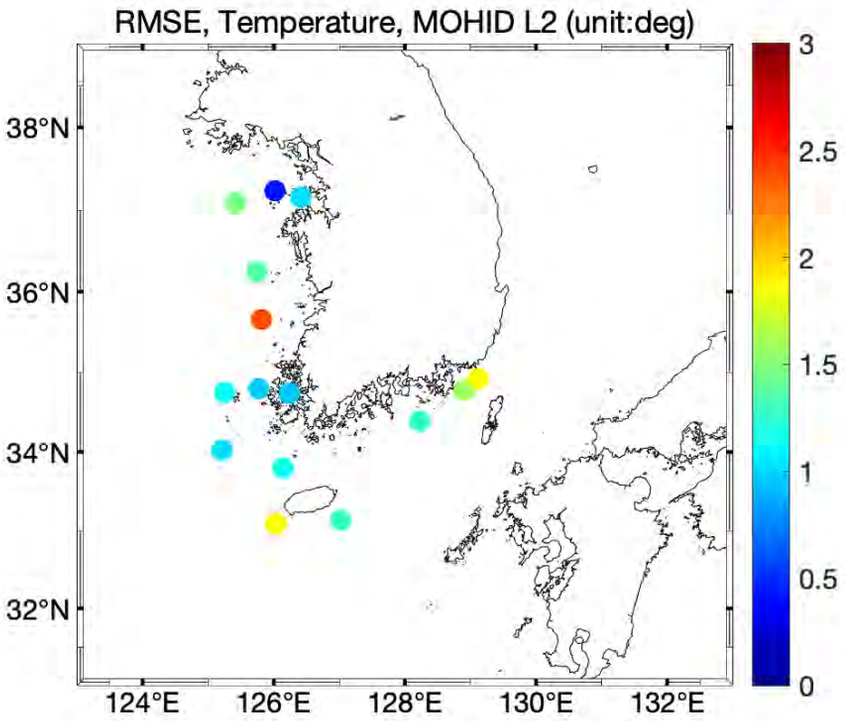


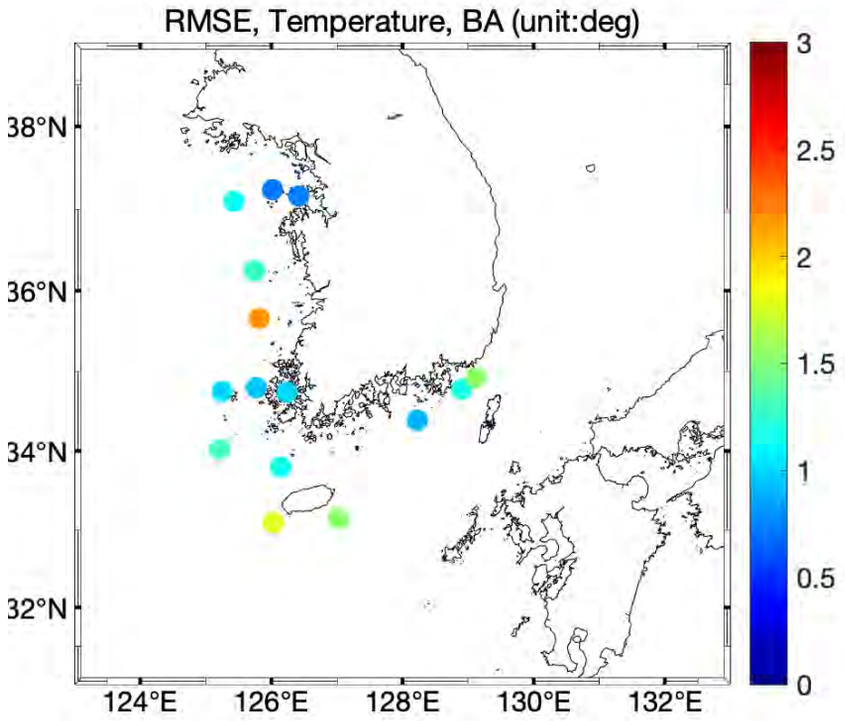




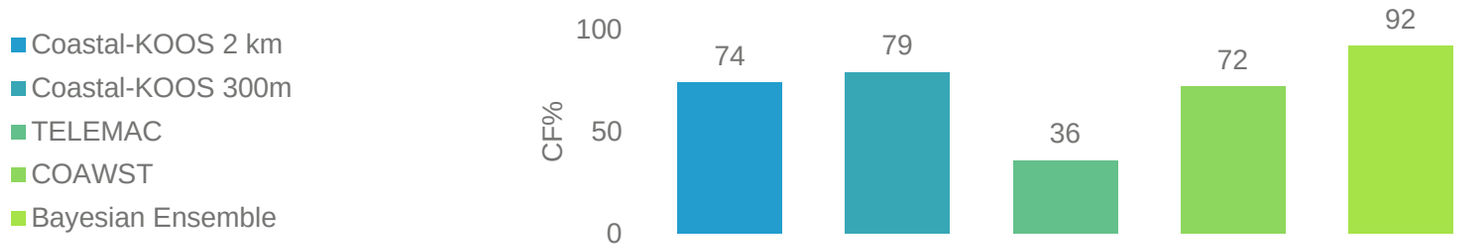


KOOS – Ensemble Prediction System

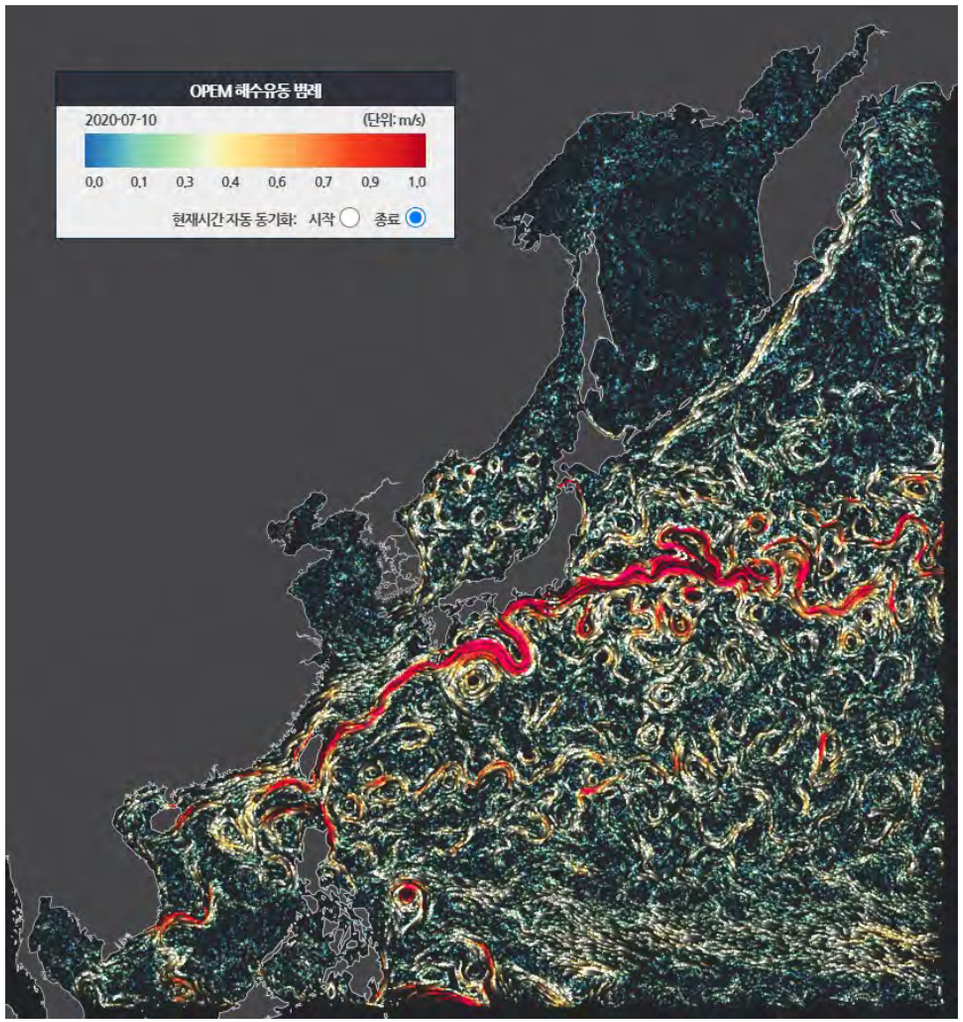


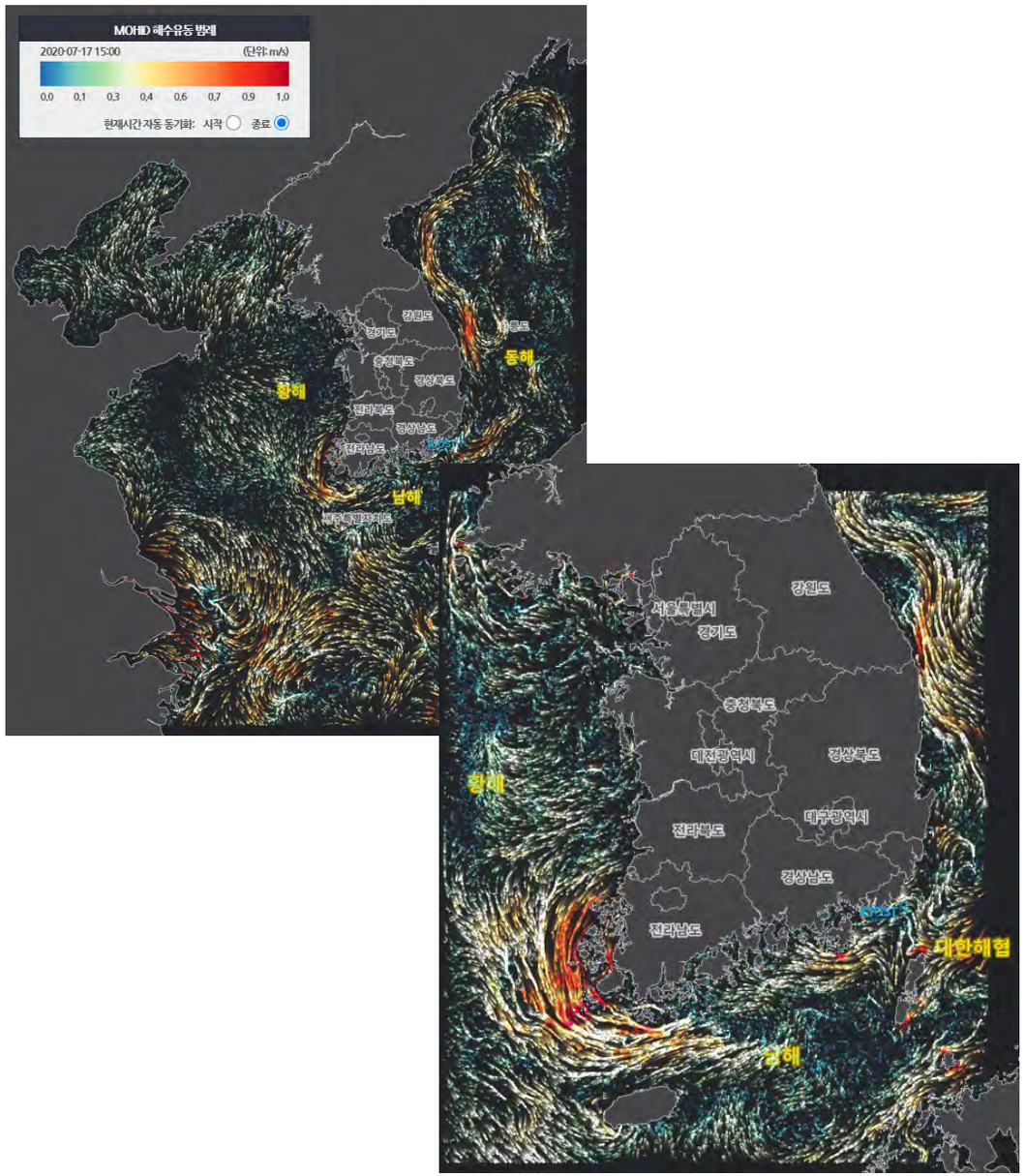


Comparison of Bayesian Ensemble Prediction



KOOS – Visualization System





Closing Remarks

- KIOST has been developed “Korea Operational Oceanographic System (KOOS)” at the request of Ministry of Ocean and Fisheries (MOF) since 2009.
- We are trying to improve a model performance and a forecasting accuracy during the three phases of the KOOS project.
- In order to achieve the successful goal of this project, a council of related organizations (industrial, academic, research, and government) has been formed to provide advice on the application of the field, identify needs, and expand joint research and cooperation.
- International cooperation continues to carry out mutual exchange and activities on the development, advancement technology, and operation of prediction systems through GODAE OP and NEAR-GOOS.
- KOOS’ capabilities are expected to have a positive impact on global cooperation.

Thank you !