Application of numerical models in UST21: From coastal to open ocean

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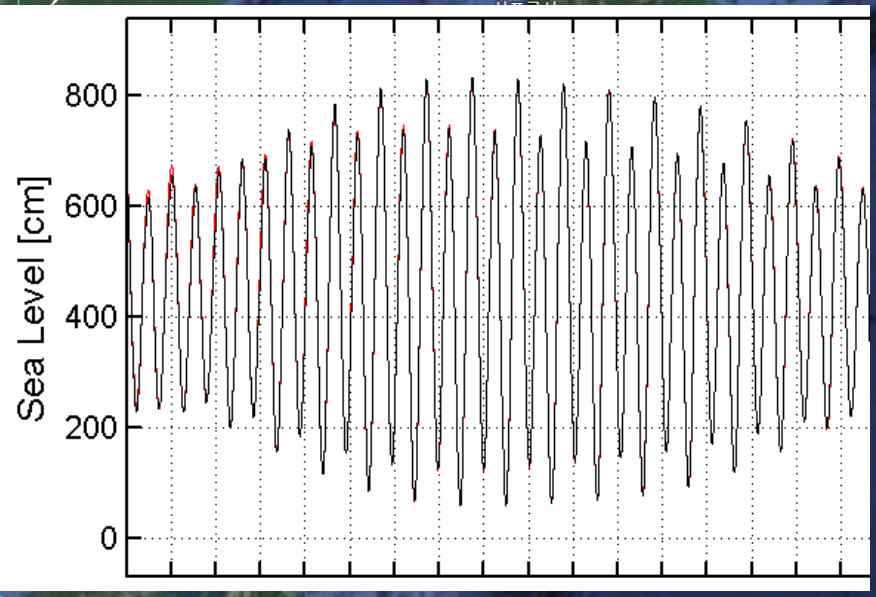
Hydrographic Survey / Offshore Support / Geophysical Survey / Resources Exploration Topographic Survey / Observations & Modeling / Charts & Thematic Maps/ MGIS & Mapping Sys.

OPST-8
Busan, 9th Nov.

Oceanic condition (wave) in Korea

- Semiclosed bay with strong tide



Yellow Sea

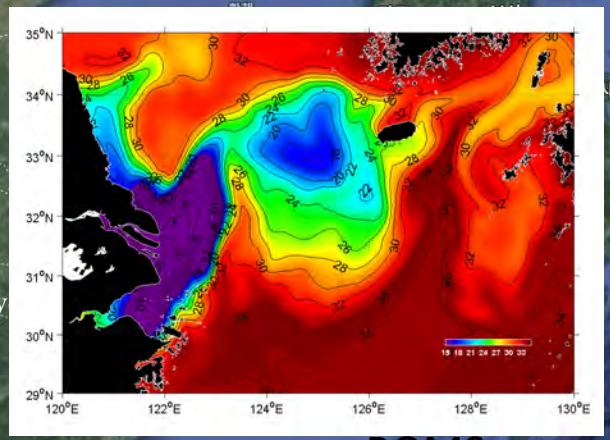
We are here

Incheon Dec. 1999

Oceanic condition (wave) in Korea

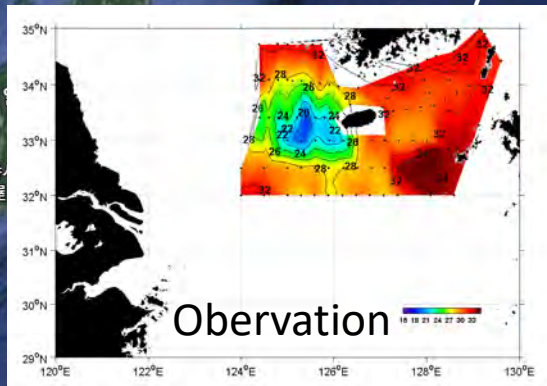
- Semiclosed bay with strong tide
- River plume

Changjiang River
World's 5th largest riv

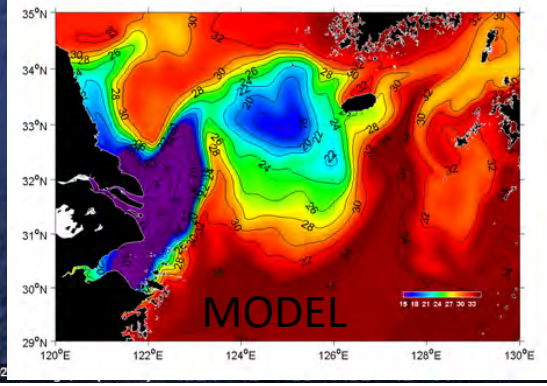


ROMS

Sea Surface Salinity



Obervation

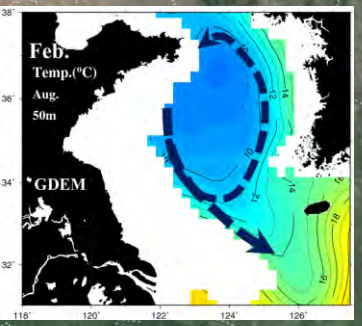


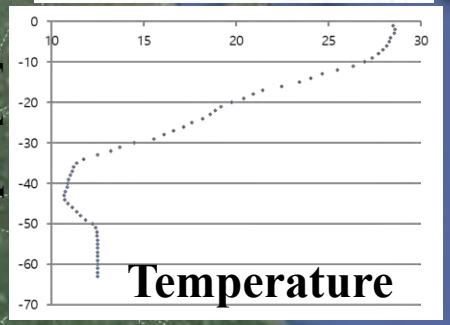
MODEL

Yellow Sea

Oceanic condition (wave) in Korea

- Semiclosed bay with strong tide
- River plume
- High turbidity
- Yellow Sea Bottom Cold Water



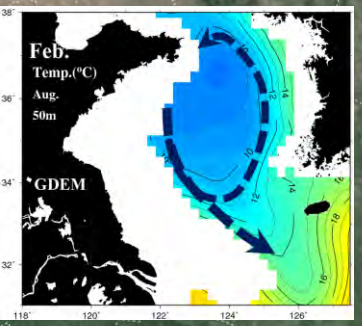


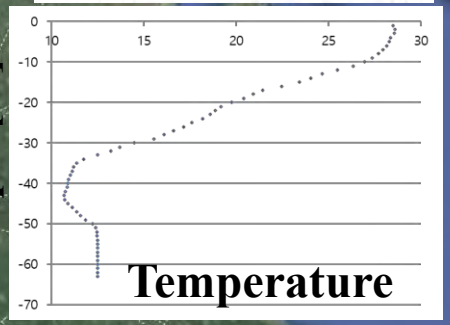
calibrate

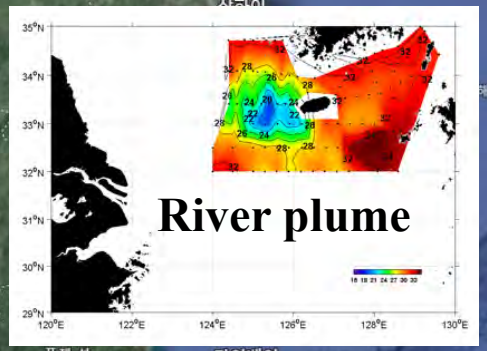
Oceanic condition (wave) in Korea

Yellow Sea

- Semiclosed bay with strong tide
- River plume
- High turbidity
- Yellow Sea Bottom Cold Water







East Sea

- Deep water; basin scale; Small tide; large influence from wave
- Western boundary current (Kuroshio, Tsushima warm current)

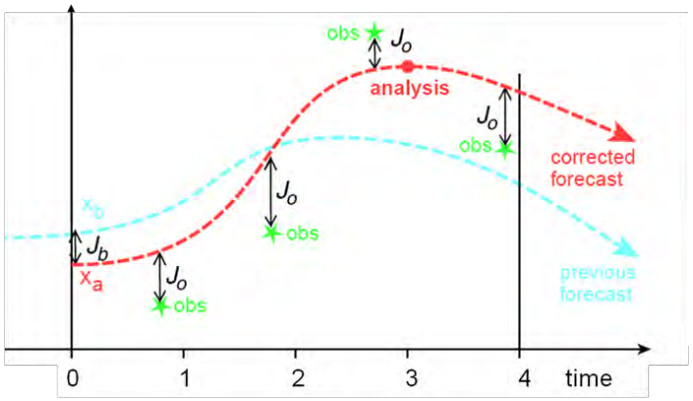
The oceanic condition around KP looks very complex.

1. Improve the forecasting performance(DA)
2. Compare of Data Assimilation Method
3. Cost effective method (Reduce DA time)
4. Apply DA to Biogeochemical coupled model

Improve the forecasting performance

Data Assimilation in Yellow Sea using 4D-Var

4Dvar



4D-Var

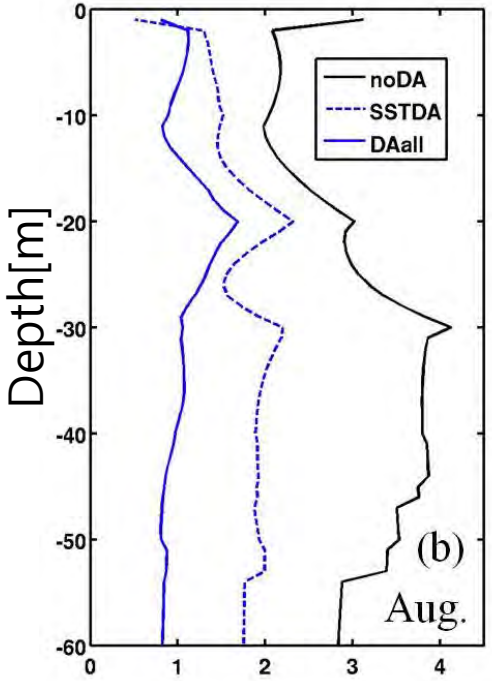
$$J = \min \frac{1}{2}[(\mathbf{x}_0 - \mathbf{x}_0^b)^{\mathrm{T}} \mathbf{B}^{-1} (\mathbf{x}_0 - \mathbf{x}_0^b) + \sum_{i=1}^{s} (H\mathbf{x}_i - \mathbf{y}_i)^{\mathrm{T}} \mathbf{R}_i^{-1} (H\mathbf{x}_i - \mathbf{y}_i)]$$

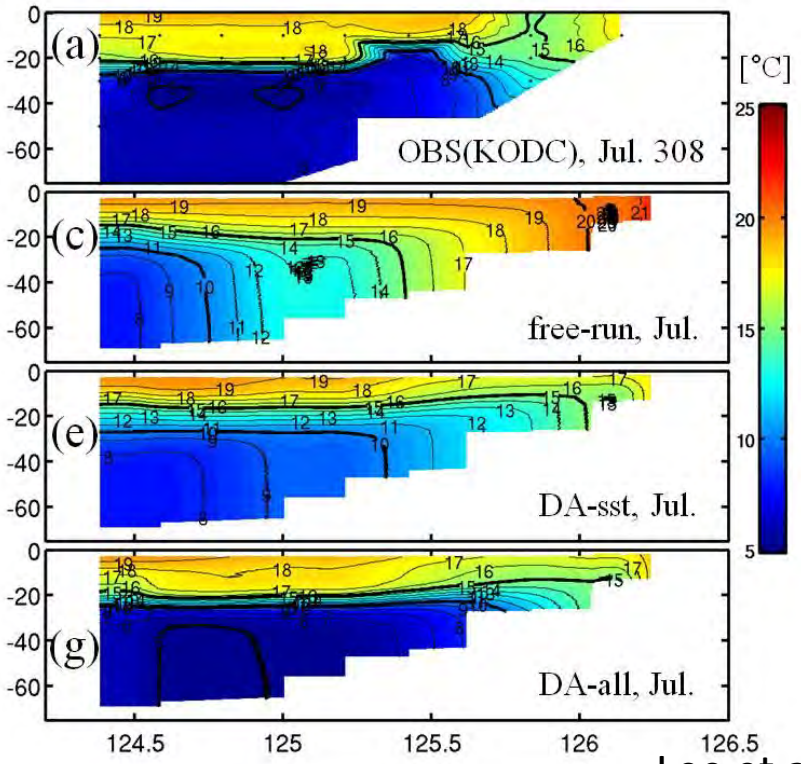
Distance to background at the initial time

Distance to observations in a **time window interval t_0-t_1**

Control variable $\mathbf{x}(t_0)$

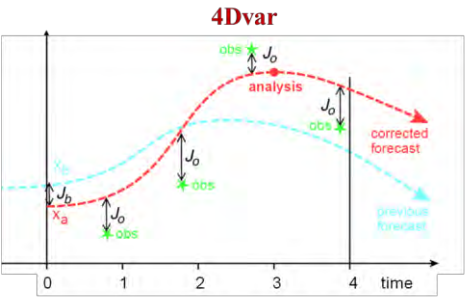
Analysis $\mathbf{x}(t_1) = M[\mathbf{x}(t_0)]$



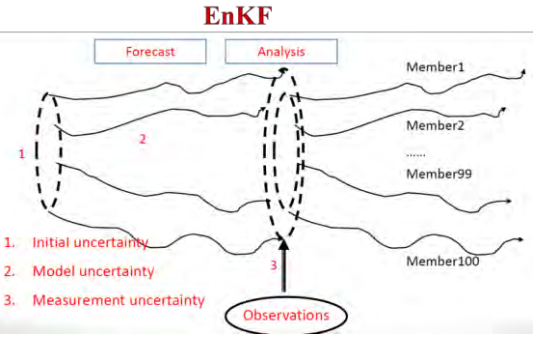


Lee et al. OSJ, 2018

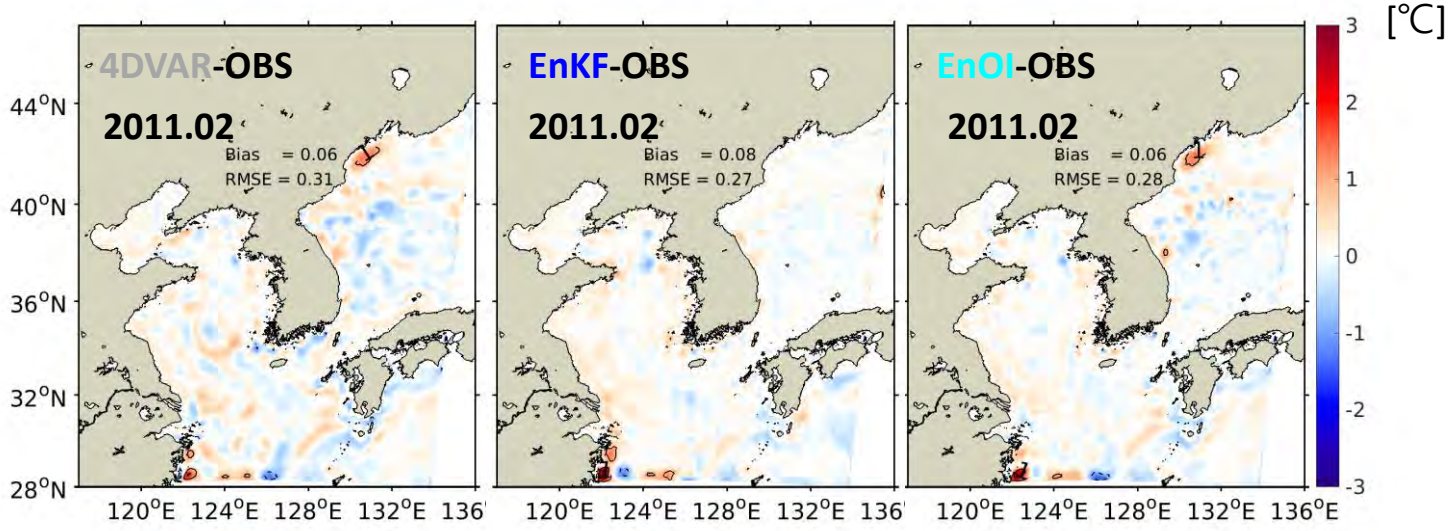
Comparison of Data Assimilation Method



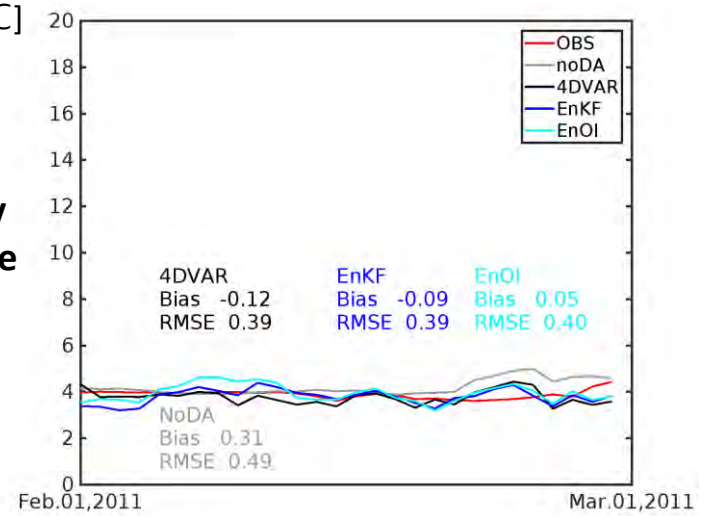
Variational method : 3dvar, 4dvar(strong, weak)



DA model Comparison(SST) avg of Feb. in 2011

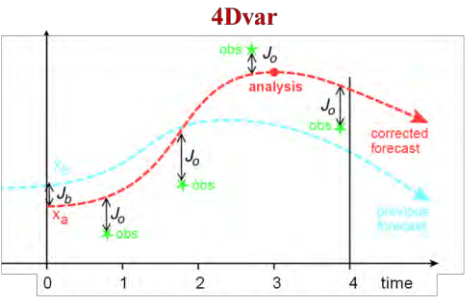


Oyeon Buoy Temperature

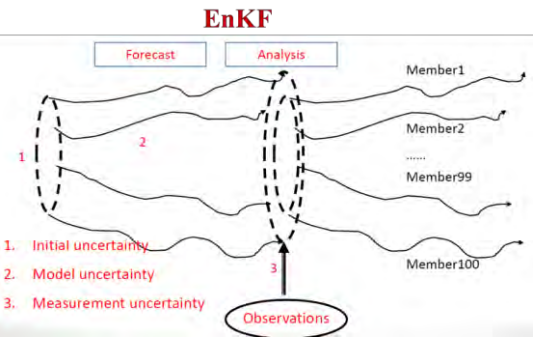


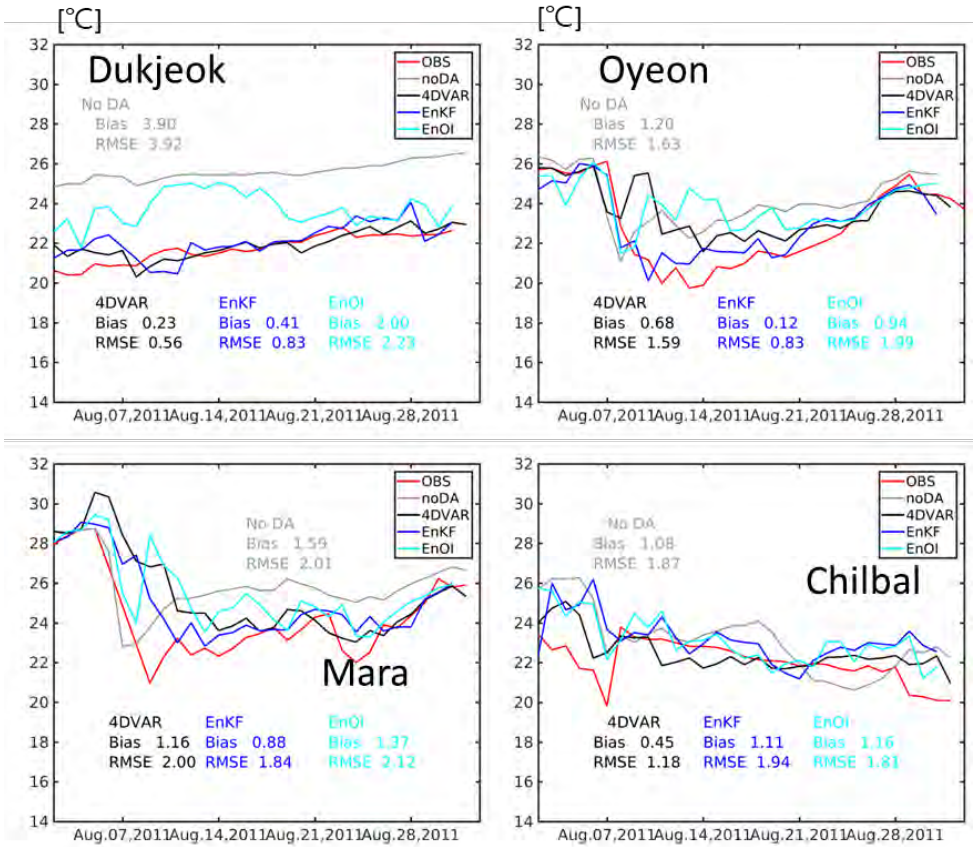
Lee et al. OPR, 2020

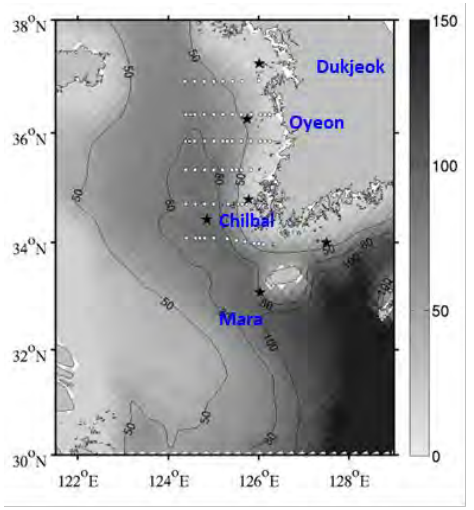
Comparison of Data Assimilation Method



Variational method : 3dvar, 4dvar(strong, weak)







Location buoy and depth

RMSE	4DVAR	EnKF	EnOI
Dukjeok	0.56	0.83	2.23
Oyeon	1.59	0.83	1.99
Mara	2.00	1.84	2.12
Chilbal	1.24	1.99	1.81
AVG.	1.35	1.37	2.03

4DVAR and EnKF shows almost same performance

Lee et al. OPR, 2020

Saving time for Data Assimilation

Incremental 4D-Var in the Inner Step with Low resolution(I4DVAR-ISL)

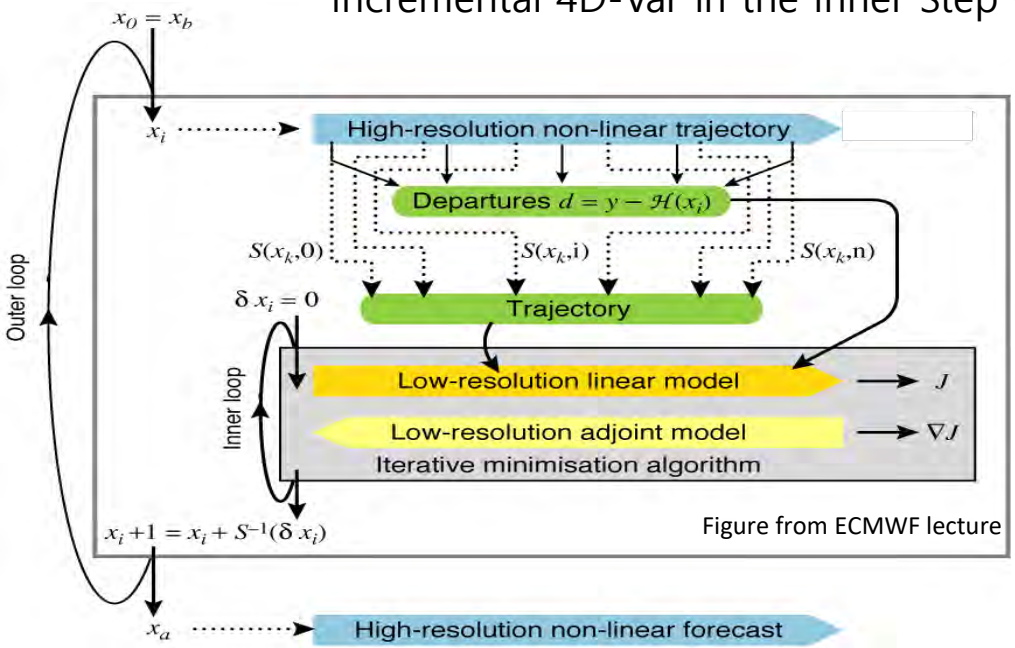
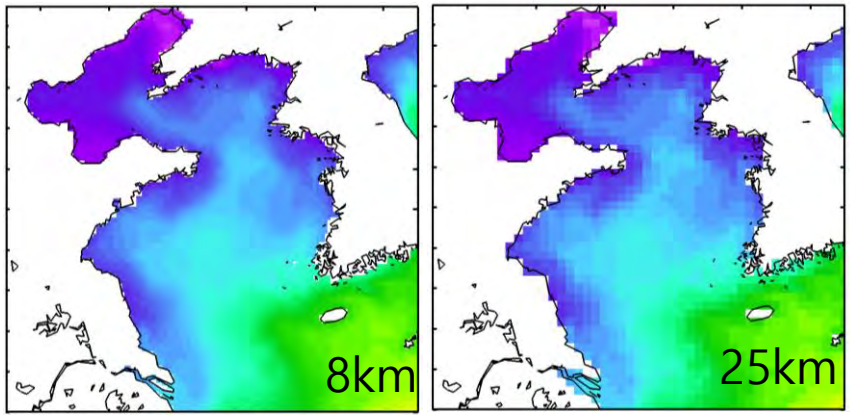
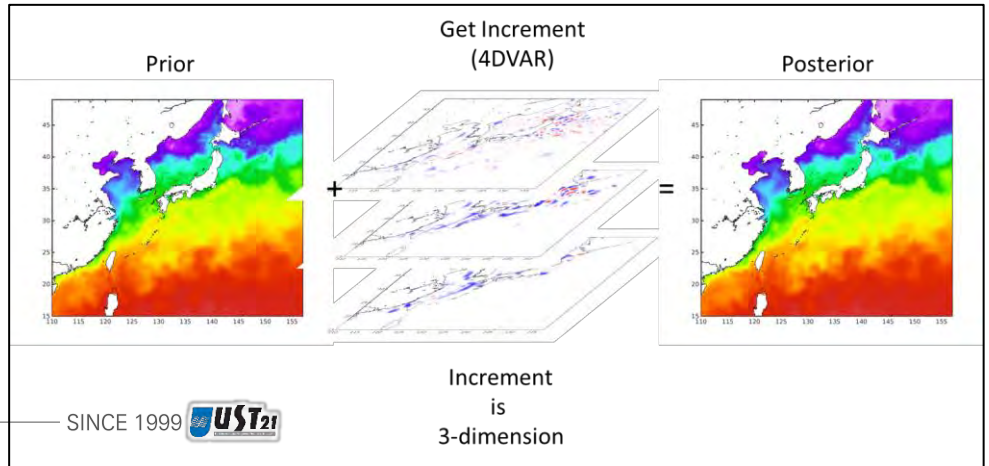
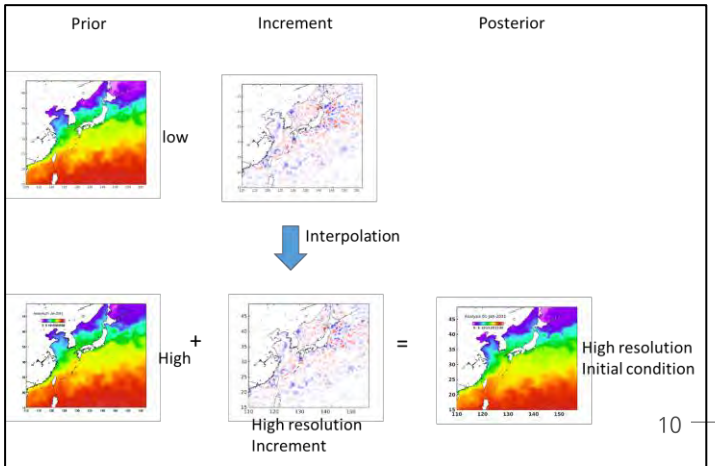


Figure from ECMWF lecture



① Interpolation High resol. IC to Low resol. IC
② Run Low resol DA model
③ Interpolate Low resol. Increment to High resol. model and add increment to High resol. IC

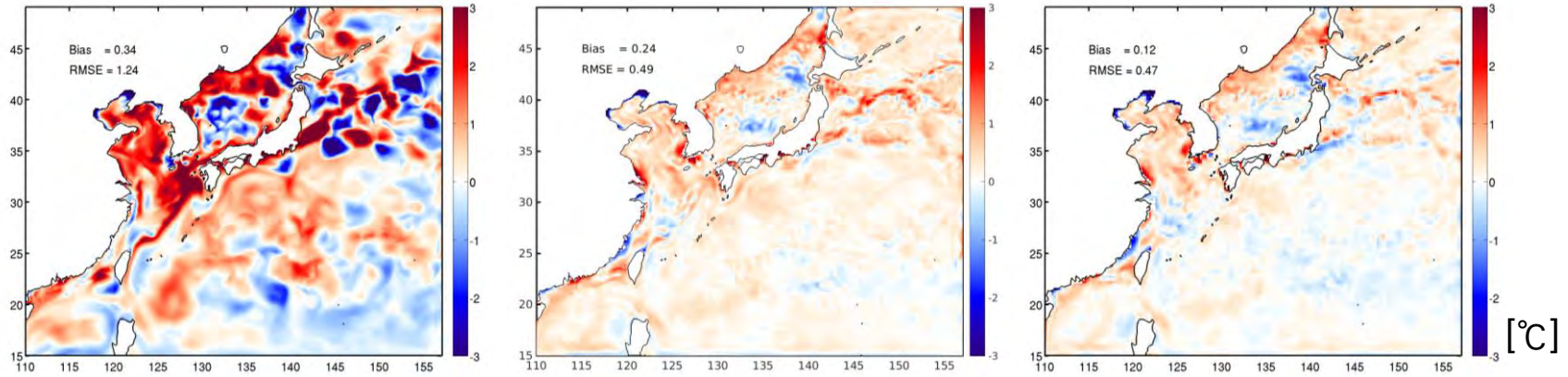




Saving time for Data Assimilation

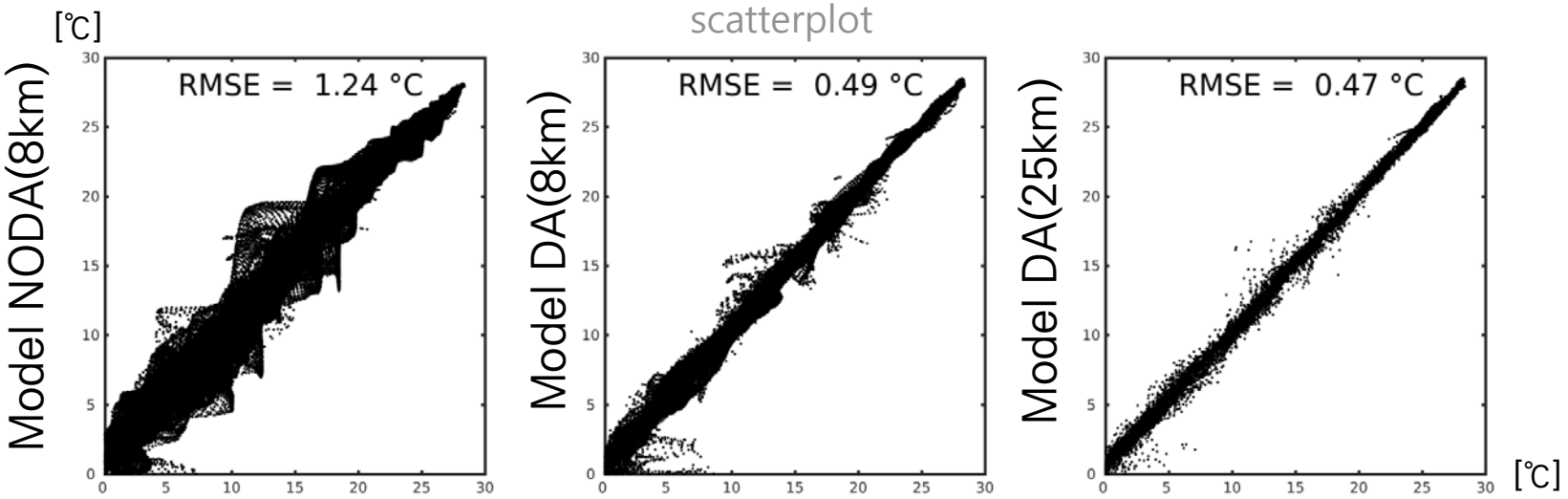
Incremental 4D-Var in the Inner Step with Low resolution(I4DVAR-ISL)

Difference map of monthly mean(Jan.) (model – OBS)



NODA(8km) DA(8km), I4DVAR-ISL DA(25km)

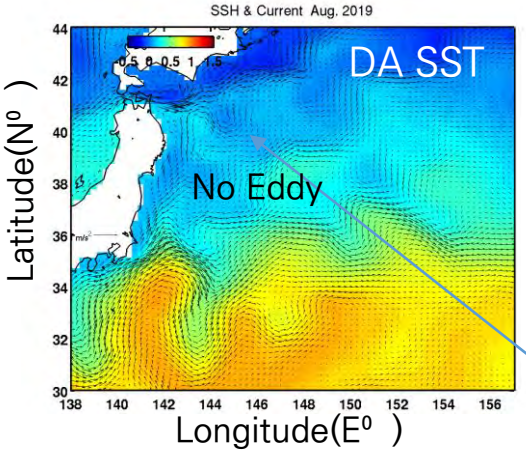
scatterplot



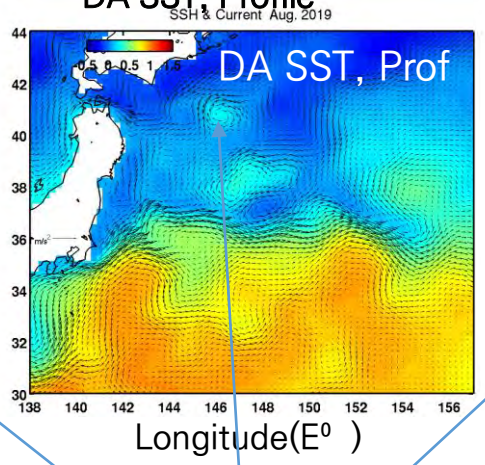
OBS OBS OBS

comparison

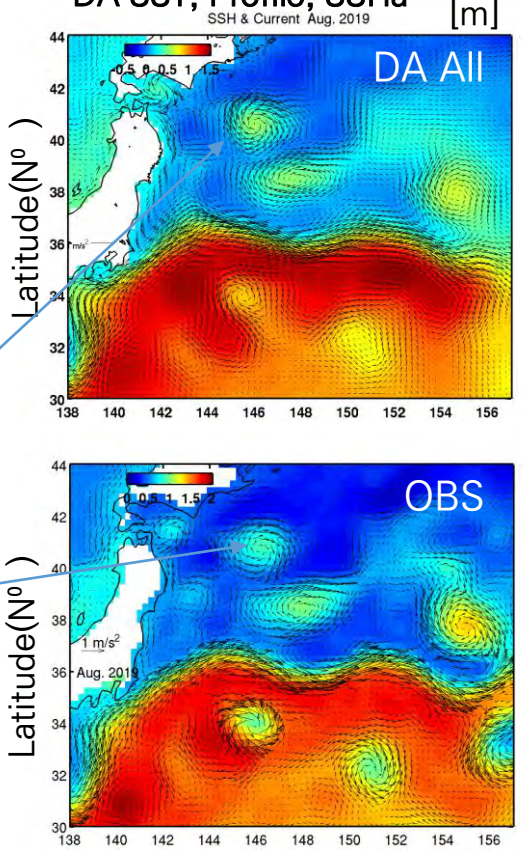
Aug. mean in 2019
DA SST



Aug. mean in 2019
DA SST, Profile



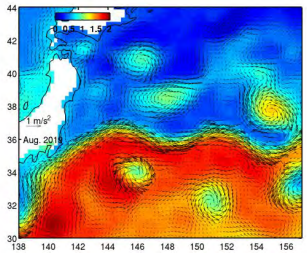
Aug. mean in 2019
DA SST, Profile, SSHa



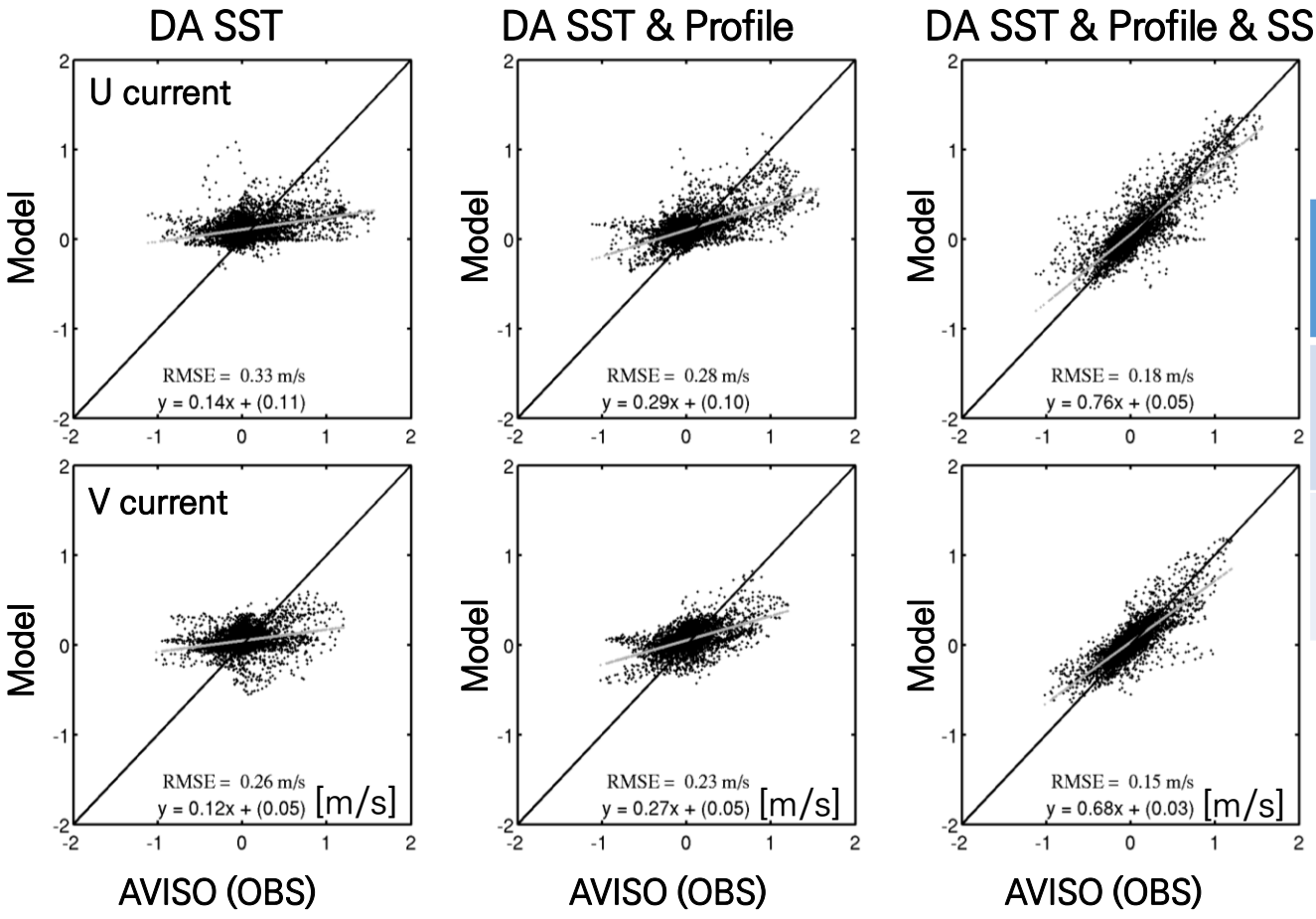
Mesoscale Eddy

CTD 등의 in-situ자료와 해면고도 자료의 동화 후 모델의 성능이 개선됨

Aug. mean in 2019
AVISO current (OBS)



Current in KOE region

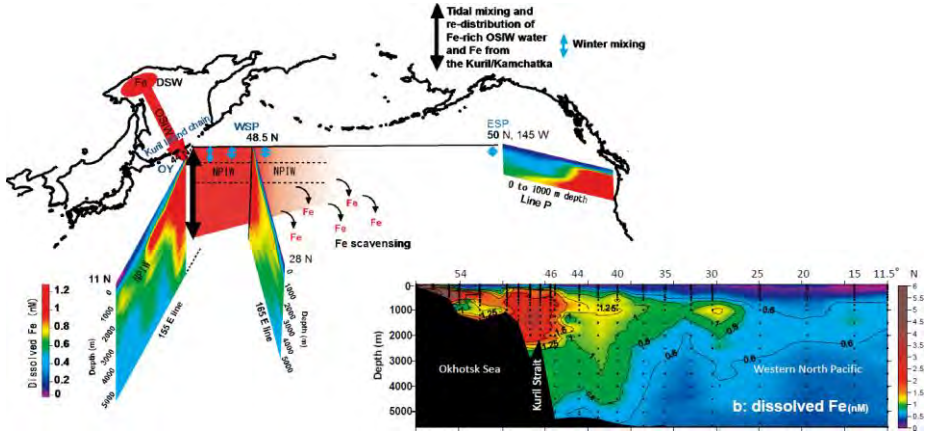


RMSE (m/s)

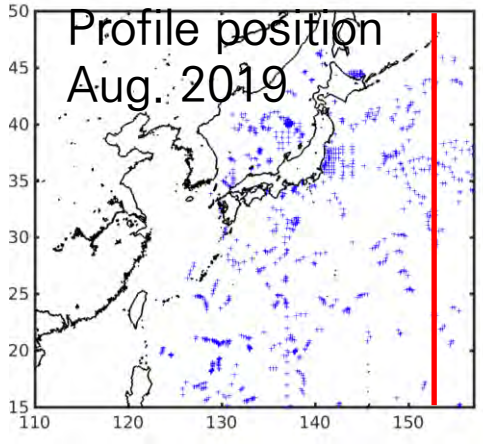
	SST	SST Prof.	SST Prof. SSH
U current	**0.33**	**0.28**	**0.18**
V current	**0.26**	**0.23**	**0.15**

More data used in assimilation better performance

North Pacific Intermediate Water (NPIW)

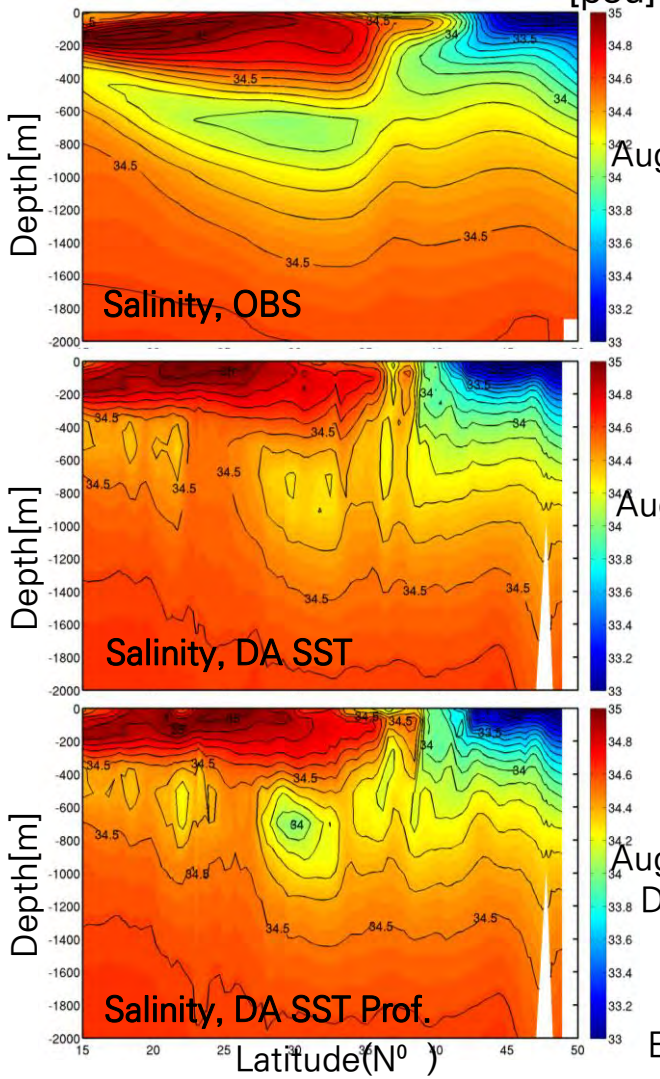


Nishioka (2013)



E 153 ^{0}

[psu]



Aug. mean in 2019
EN4 (OBS)

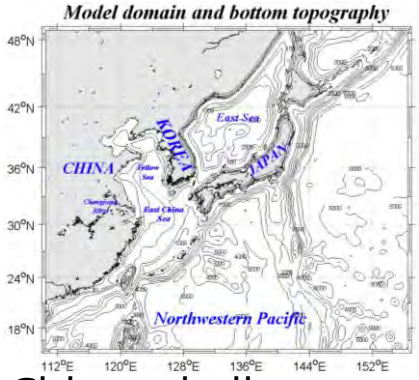
Aug. mean in 2019
DA SST

Aug. mean in 2019
DA SST, Profile

E 153 ^{0}

Application of Physical Data Assimilation model

Physical + biogeochemical coupled model



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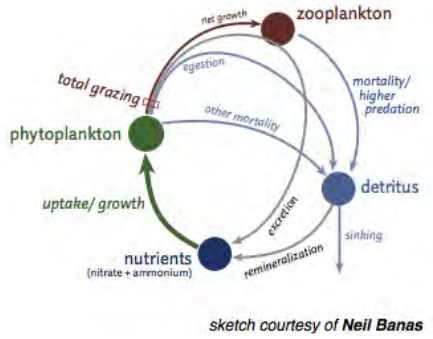
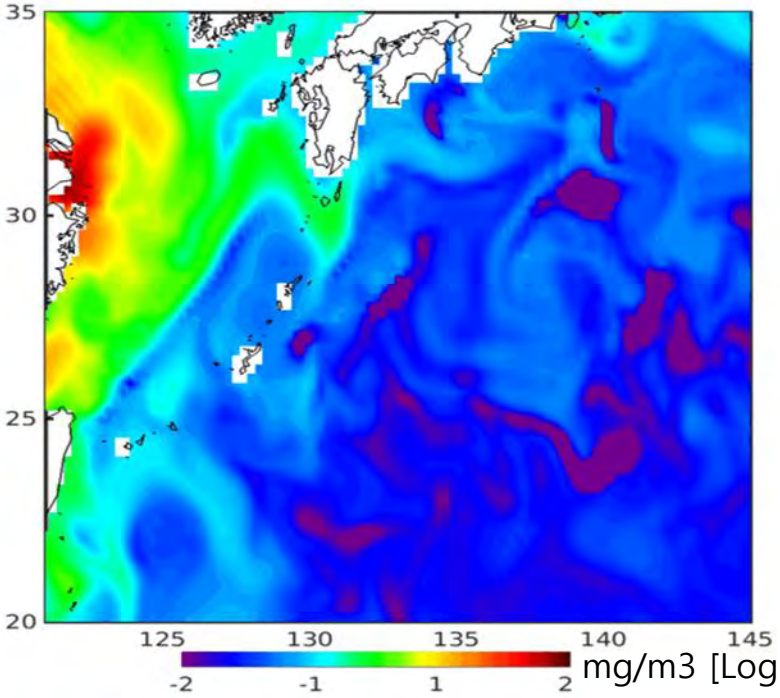
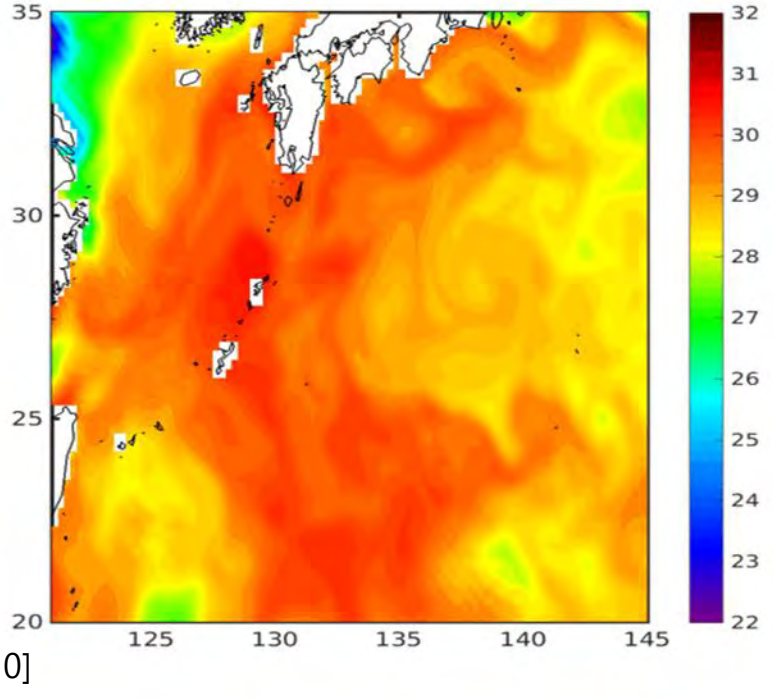


Low trophic biological model
NPZD model

Surface Chlorophyll



Sea surface Temparature

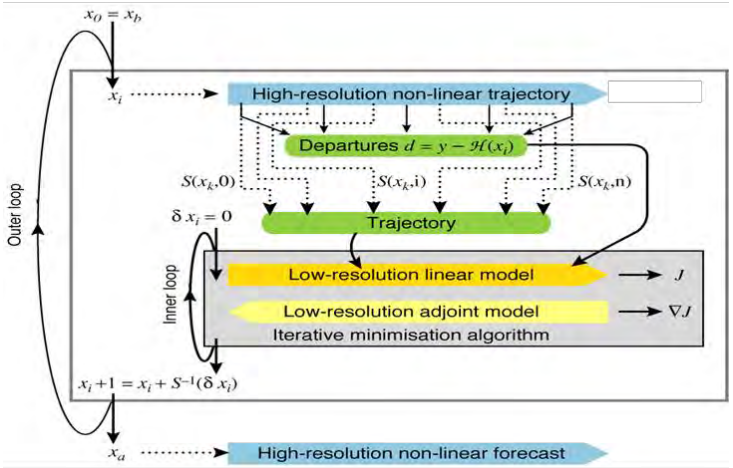


- Ocean response after typhoon in 2012
- SST cooling, Chlorophyll bloom

Application of Physical Data Assimilation model

Physical + biogeochemical coupled model

I4DVAR-ISL



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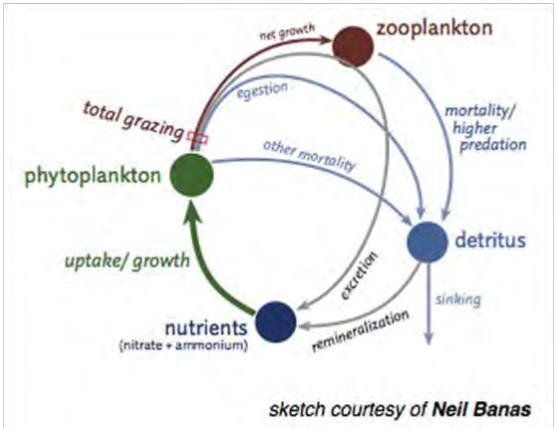
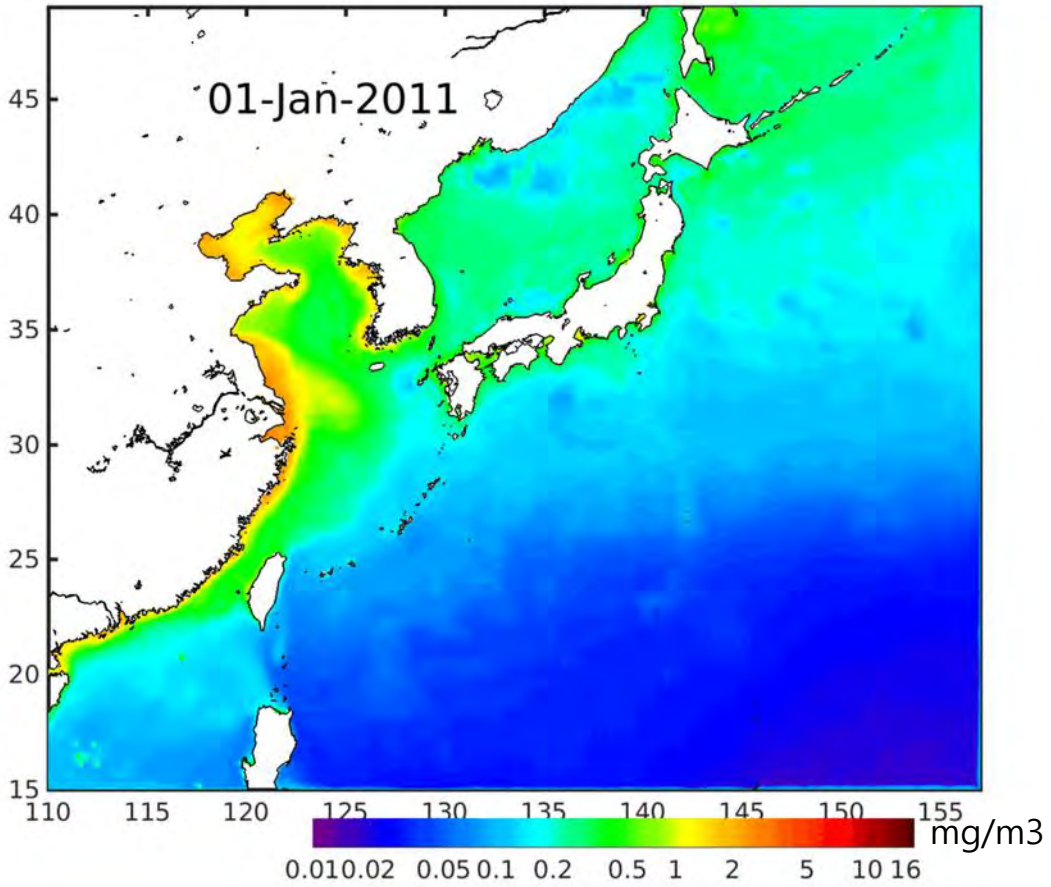
NPZD FENNEL



FENNEL (4DVAR-ISL NPZD)

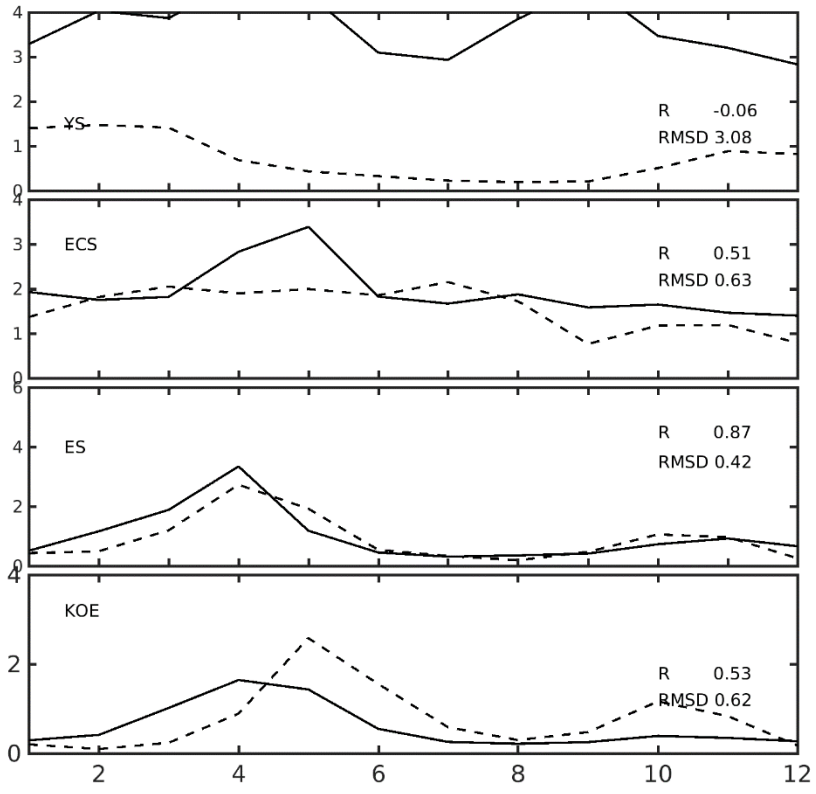


Physical data (SSH, Temp., Salt.) are assimilated (No bio. data assimilated)

Application of Physical Data Assimilation model

Physical + biogeochemical coupled model

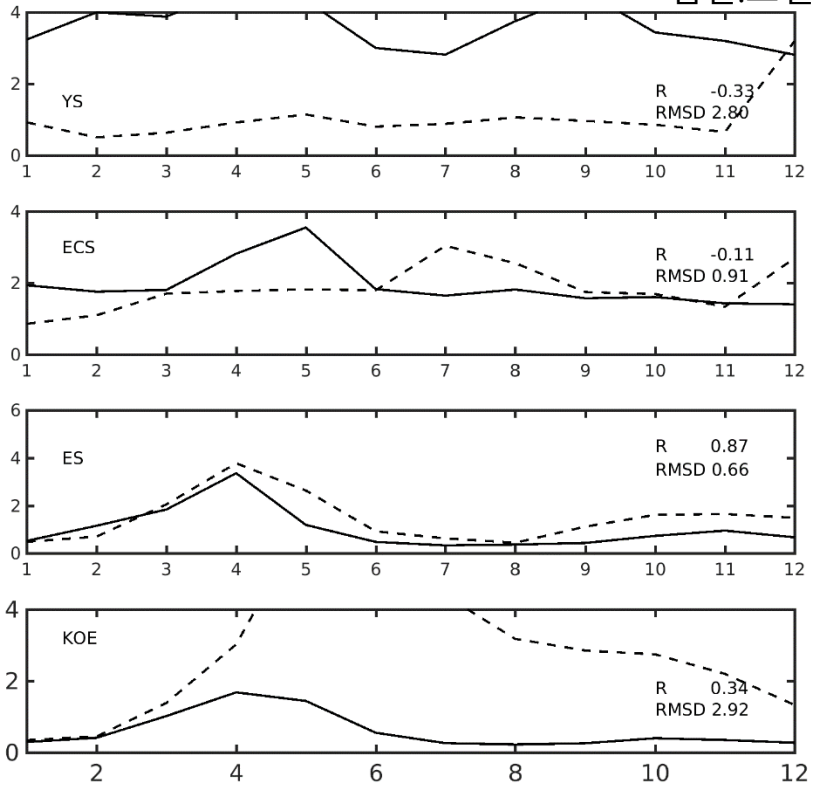
FENNEL (No DA)



시간(month) in 2011

FENNEL (4DVAR-ISL)

실선:관측
점선:모델



시간(month) in 2011

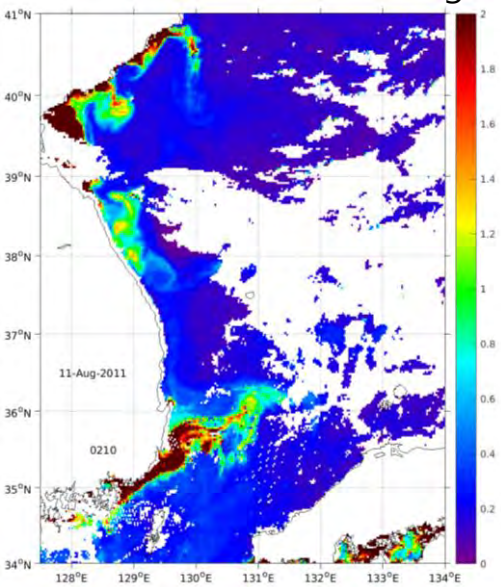
Combine result and put one figure

Application of Physical Data Assimilation model

Physical + biogeochemical coupled model

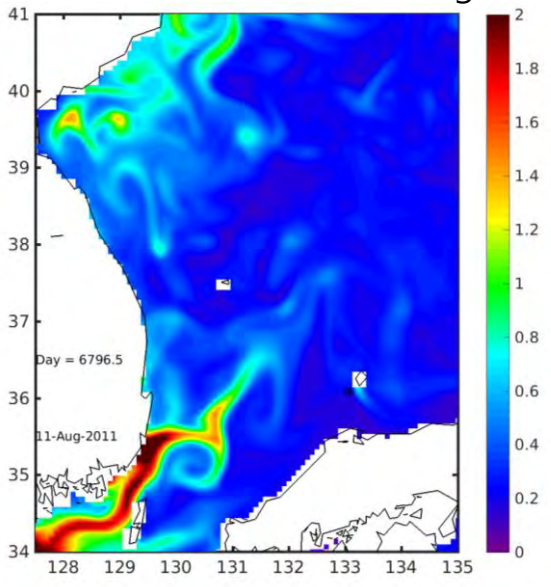
Chlorophyll 11th Aug. 2011

mg/m3



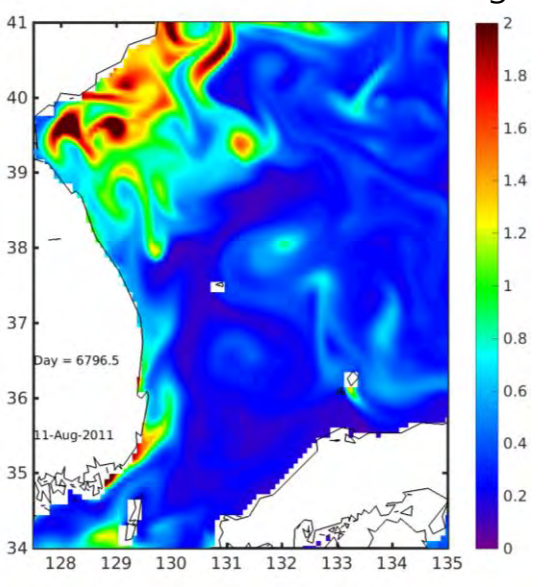
OBS(MODIS)

mg/m3



Model(4DVAR ISL)

mg/m3



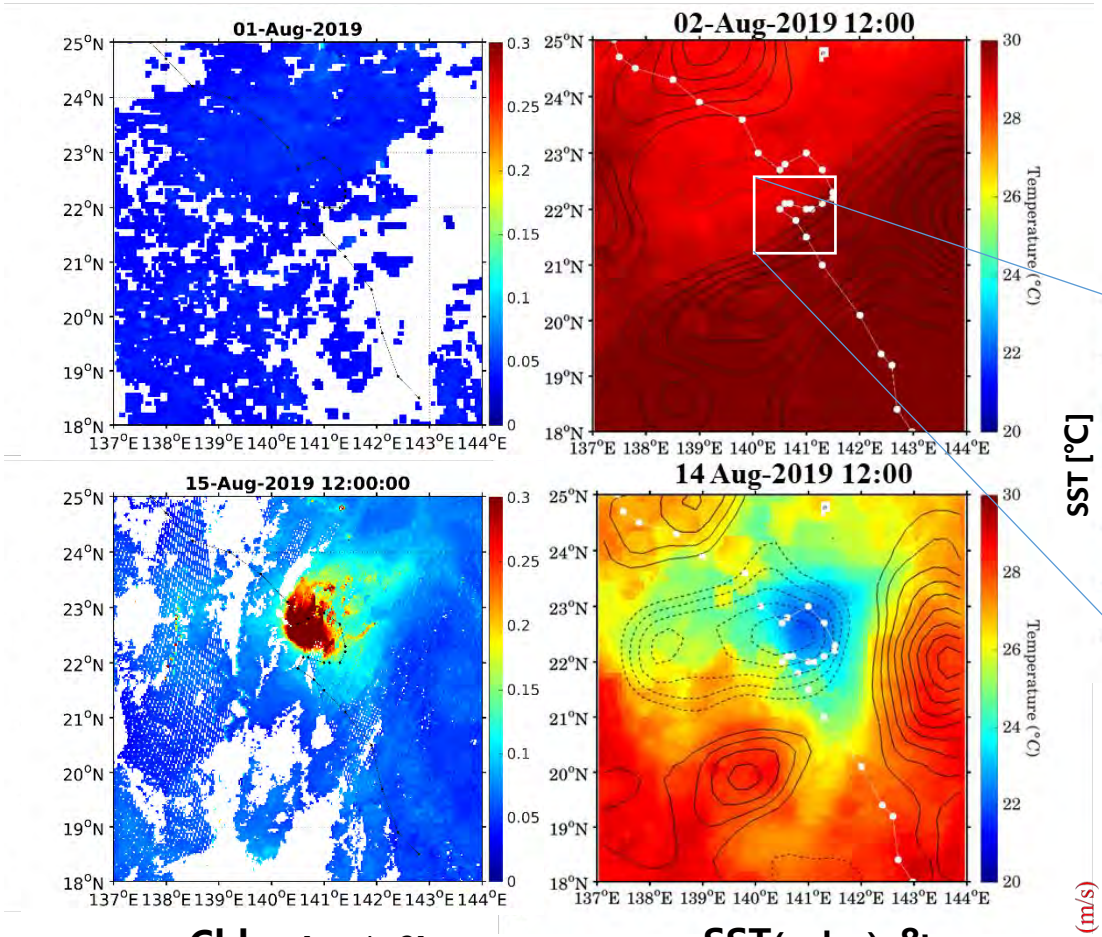
Model(NoDA)

Application of Physical Data Assimilation model

Physical + biogeochemical coupled model

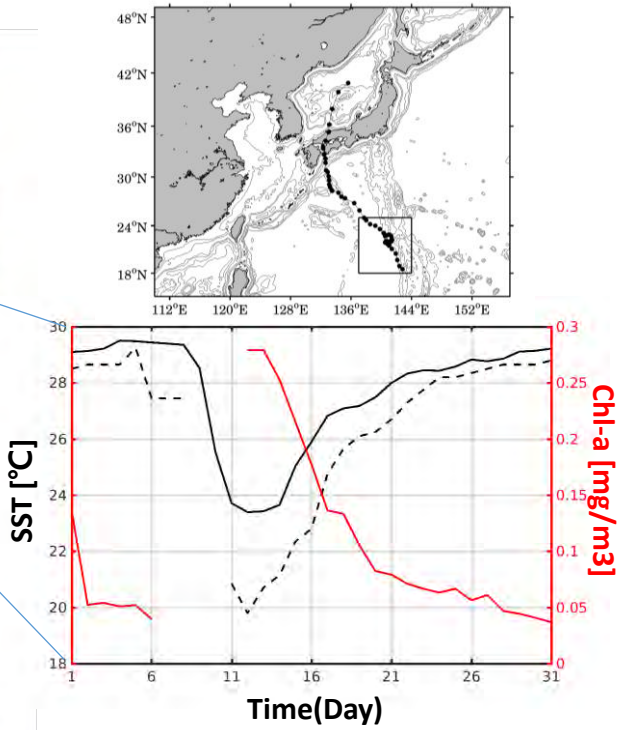
Pre Storm

Post Storm

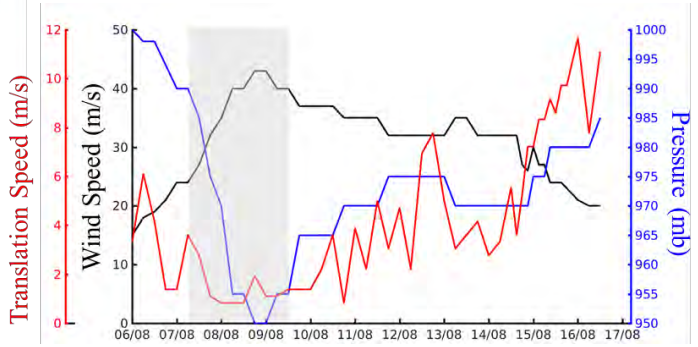


Chl-a [mg/m3]

SST(color) & SSHa(contour)



Time series of area mean (140-142E, 21-22.5N)

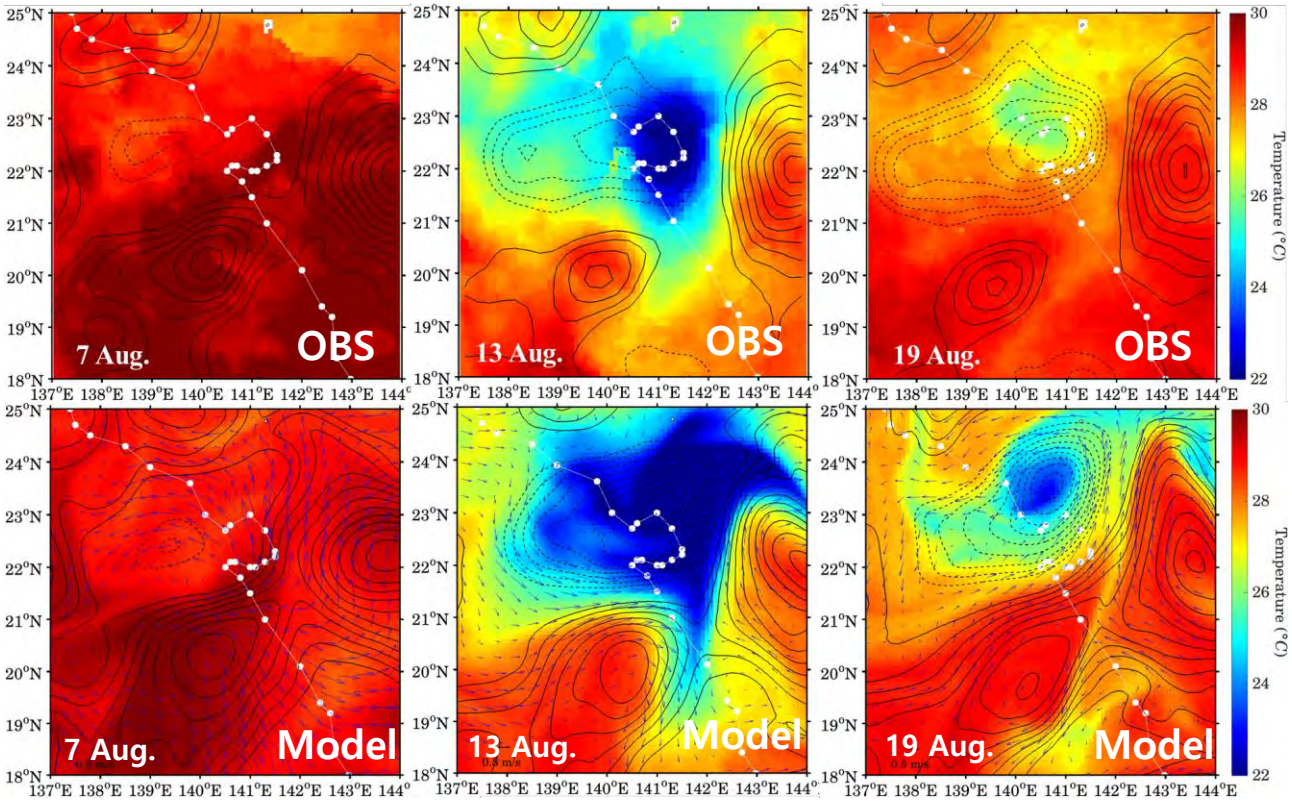


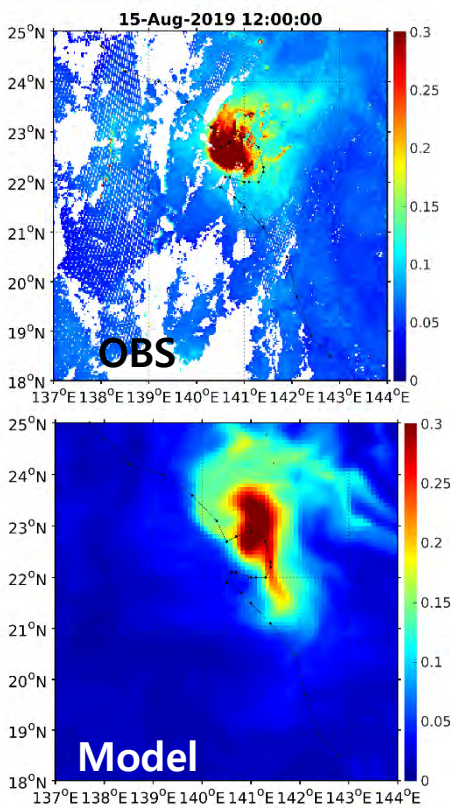
REMSS SST (black line)
AMSR SST (dashed line)
Chla (red line)

Lee et al. JMSE, 2020

Application of Physical Data Assimilation model

Physical + biogeochemical coupled model

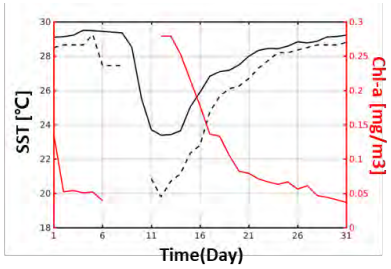




SST(color) & SSHa(contour)

Chl-a [mg/m3]

- Model accurately simulate the cooling of sea surface temperature (SST) and changes in SSH caused by typhoons
- The difference in SST cooling in the observations (REMSST) appears weaker due to the synthetic nature of the cooling
- Compared to observations, the distribution of Chl-a blooms is well reproduced in terms of its spatial distribution



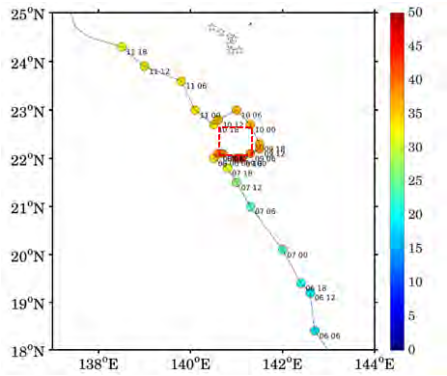
Lee et al. JMSE, 2020

Application of Physical Data Assimilation model

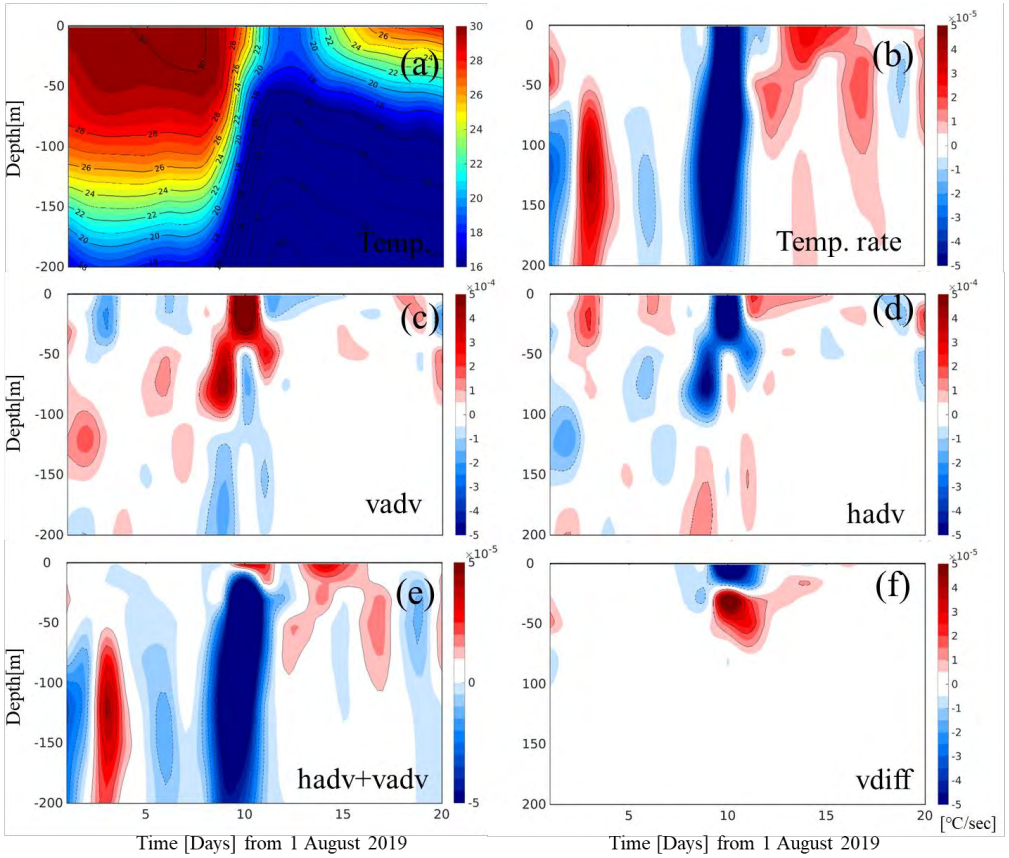
Physical + biogeochemical coupled model

$$\frac{\partial T}{\partial t} = -\left(\frac{\partial (uT)}{\partial x} + \frac{\partial (vT)}{\partial y} + \frac{\partial (wT)}{\partial z}\right) + k_h \nabla_h^2 T + k_z \frac{\partial^2 T}{\partial z^2}$$

(b) (d) (c) (f)



Time–depth diagram of model simulated at the looping area (140.5~141.5E, 22.0~22.5N)



(a) temperature, (**b**) temperature change rate term, (**c**) vertical advection term, (**d**) horizontal advection term, (**e**) sum of horizontal and vertical advection terms (**f**) vertical diffusion term.

- Upwelling and vertical mixing

Lee et al. JMSE, 2020

Application of model (KOOS) result

➢ Offshore wind farm

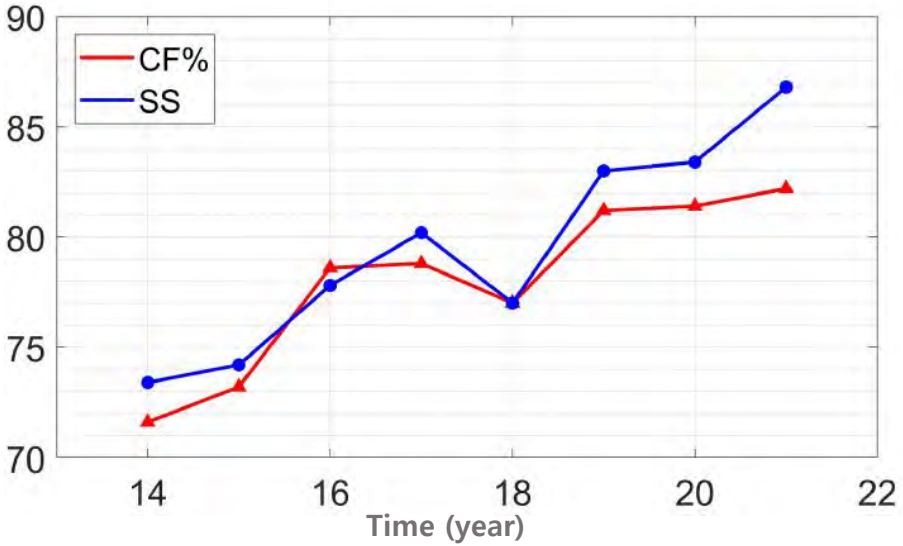
As offshore wind farm is becoming an large demanding field, we spend lots of effort working related with offshore wind farm

A good example of application of coastal modelling

Unfortunately I can not show the results due to the security reason

Application of model (KOOS) result

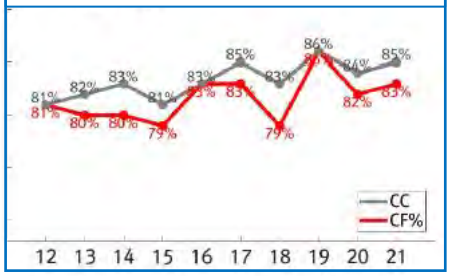
➢ KOOS (Korea Operational Oceanography System)



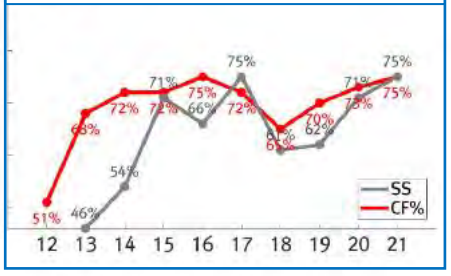
❖ KOOS system

- Supported by government since 2008
- Real time Prediction started from 2014
- Precision is gradually increasing
- UST21 Adopted KOOS as of 2021

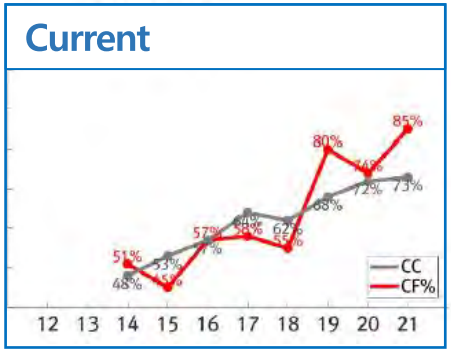
Wind



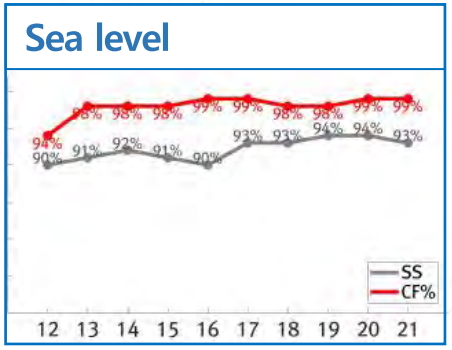
Wave



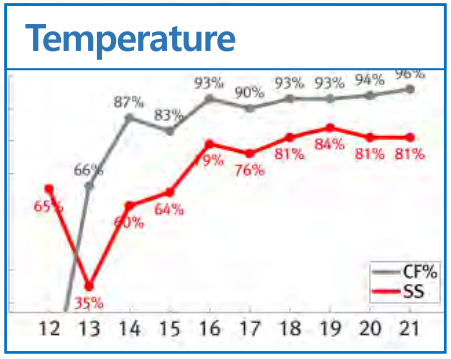
Current



Sea level



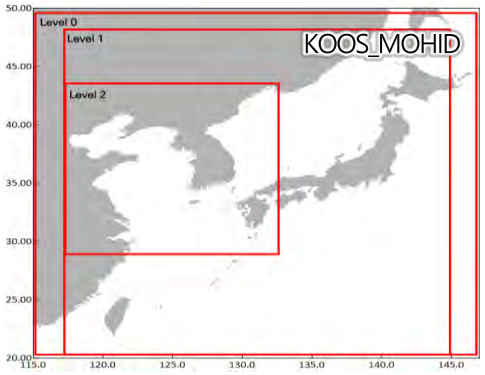
Temperature

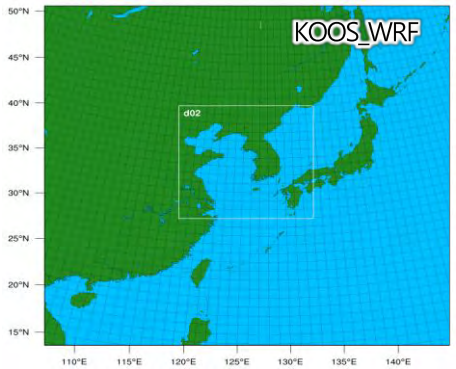


SS: Skill Score, CF: Central Frequency

Application of model (KOOS) result

➢ KOOS (Korea Operational Oceanography System)

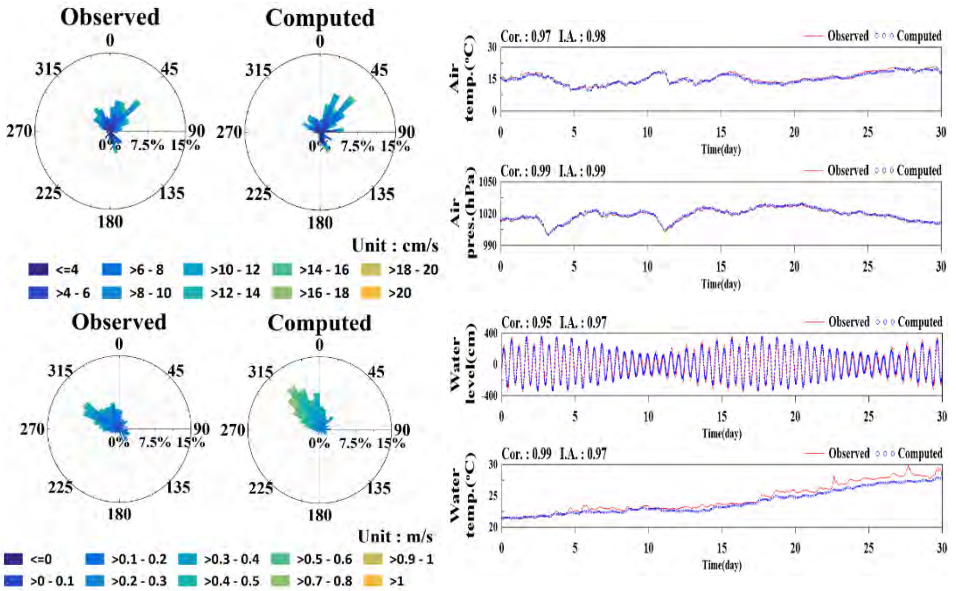




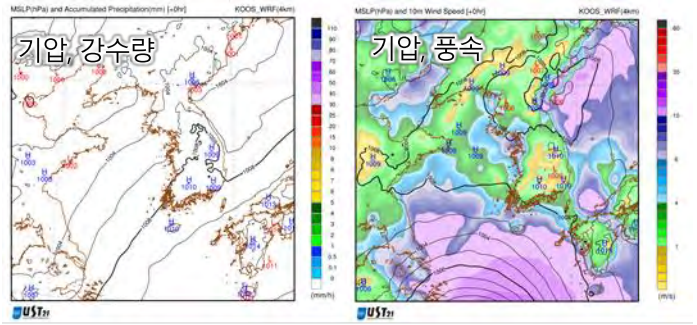
Domain of KOOS

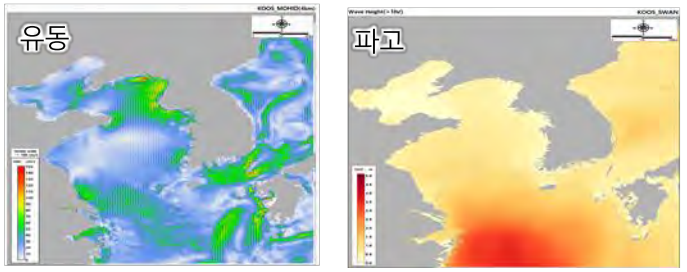
❖KOOS system

- Supported by government since 2008
- Real time Prediction started from 2014
- UST21 Adopted KOOS as of 2021
- Model run every day predicting 72 hr



Verification with Observation

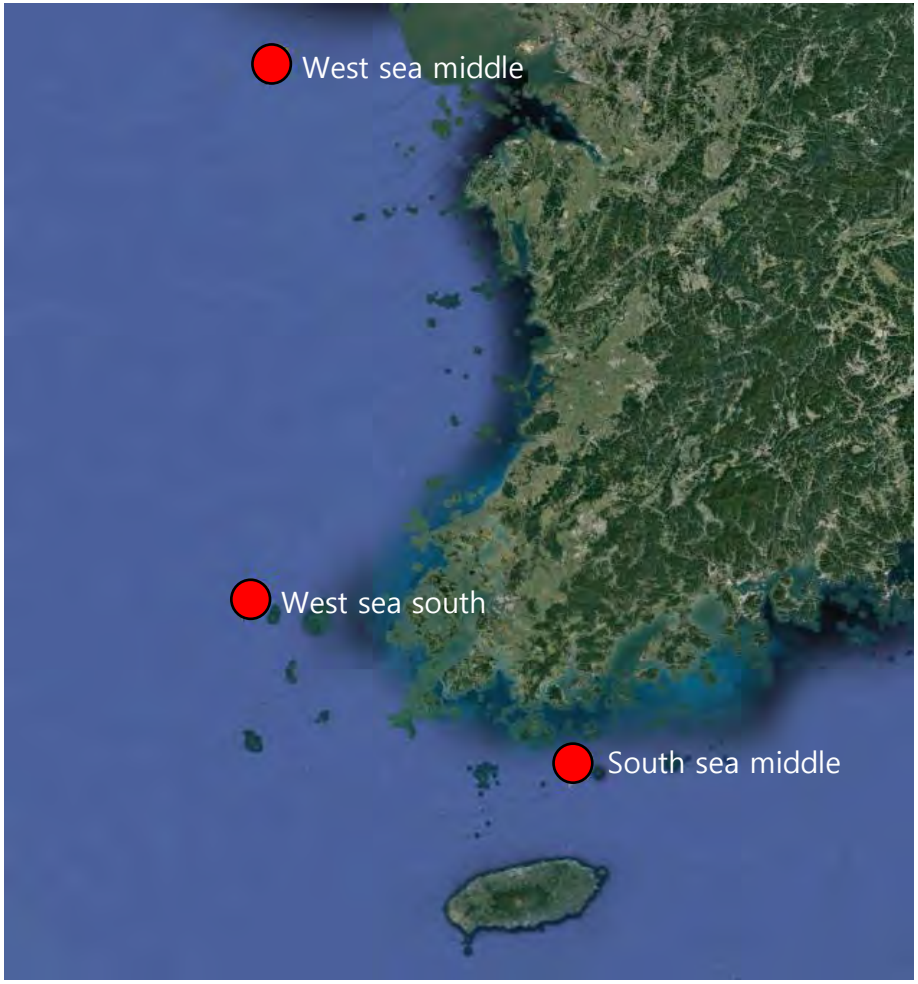




Prediction of atmosphere, ocean circulation and wave

Application of model (KOOS) result

❖Estimating Vessel Operation Days Using a Near Real-Time Prediction System



standard for calculating vessel operational days

Activities	Wind Speed (m/s)	Tidal Current (m/s)	Wave Height (m)
Survey	10.29	0.77	1.5
ROV	5.14	0.40	1.5

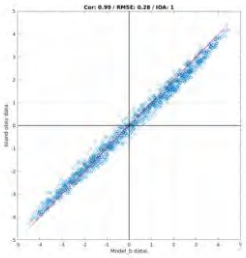
Survey, ROV Estimating the available operational period

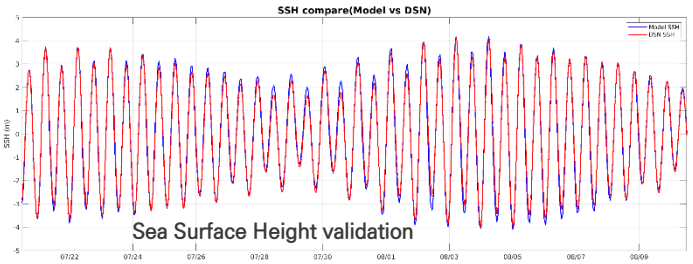
Area	Activities	Work Day (Day)
West sea middle	Survey	278
	ROV	51
West sea south	Survey	304
	ROV	57
South sea middle	Survey	286
	ROV	80

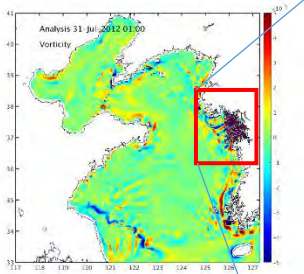
일 평균	풍속	유속	파고	Survey 및 Sampling	ROV
2022-03-01	8.25	0.41	1.06	가능	불가능
2022-03-02	8.34	0.46	1.08	가능	불가능
2022-03-03	5.79	0.49	0.61	가능	불가능
2022-03-04	6.72	0.52	0.88	가능	불가능
2022-03-05	10.63	0.48	1.35	불가능	불가능
2022-03-06	9.09	0.41	1.34	가능	불가능
2022-03-07	5.22	0.39	0.80	가능	불가능
2022-03-08	3.90	0.35	0.32	가능	가능
2022-03-09	3.98	0.30	0.30	가능	가능
2022-03-10	2.36	0.31	0.28	가능	가능
2022-03-11	2.49	0.31	0.47	가능	가능
2022-03-12	1.90	0.28	0.49	가능	가능
2022-03-13	5.23	0.36	1.10	가능	불가능
2022-03-14	4.37	0.34	0.73	가능	가능
2022-03-15	4.01	0.28	0.73	가능	가능
2022-03-16	2.56	0.31	0.34	가능	가능
2022-03-17	10.52	0.38	1.36	불가능	불가능
2022-03-18	10.79	0.47	2.24	불가능	불가능
2022-03-19	9.45	0.44	1.63	불가능	불가능
2022-03-20	6.11	0.45	1.10	가능	불가능
2022-03-21	5.61	0.46	0.62	가능	불가능

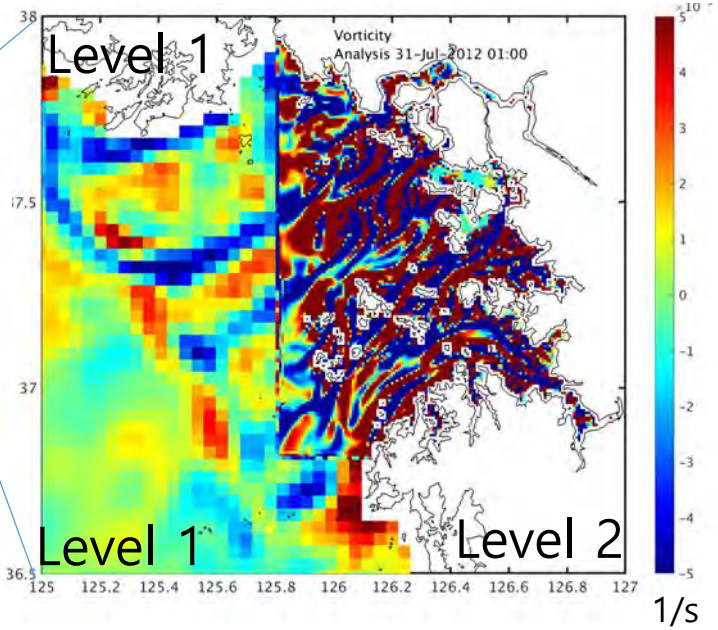
Identify the causes of erosion

-The purpose of this research is to identify the causes of erosion in the Puldeung sand shoals
-Model realistically simulates sea level changes
-Given that the Gyeonggi Bay is a region strongly influenced by tides, it is critical to determine the appropriate bottom friction coefficient



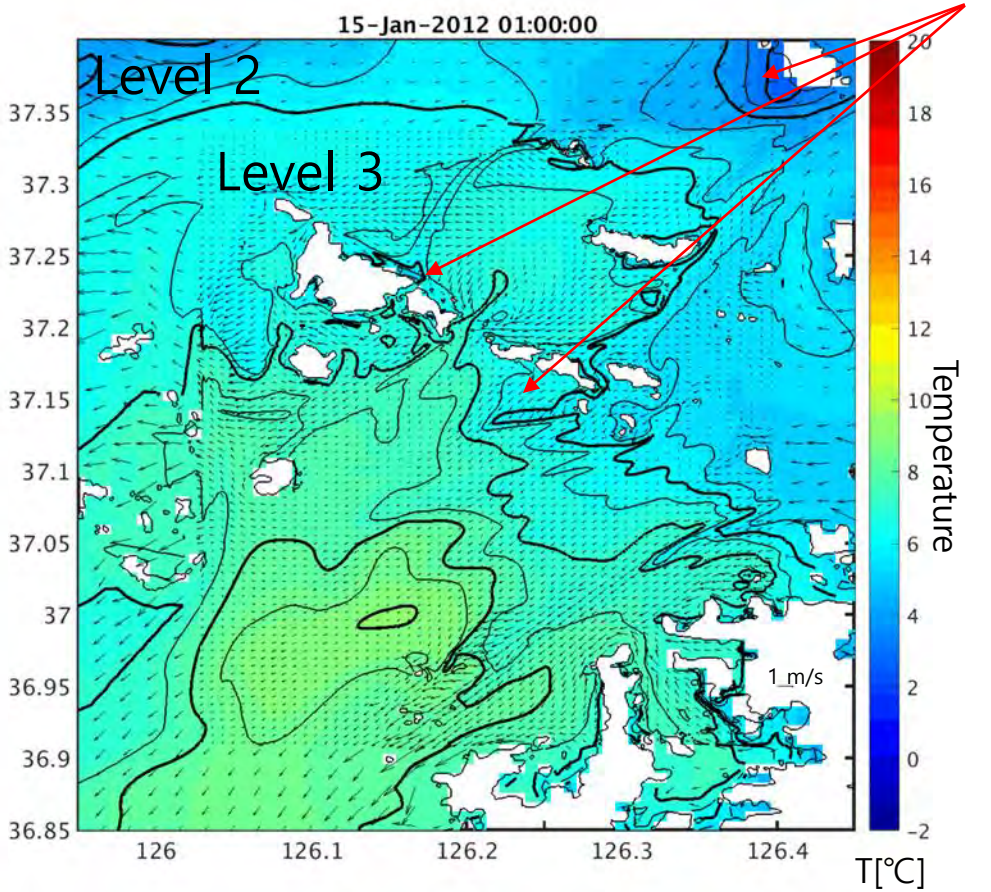






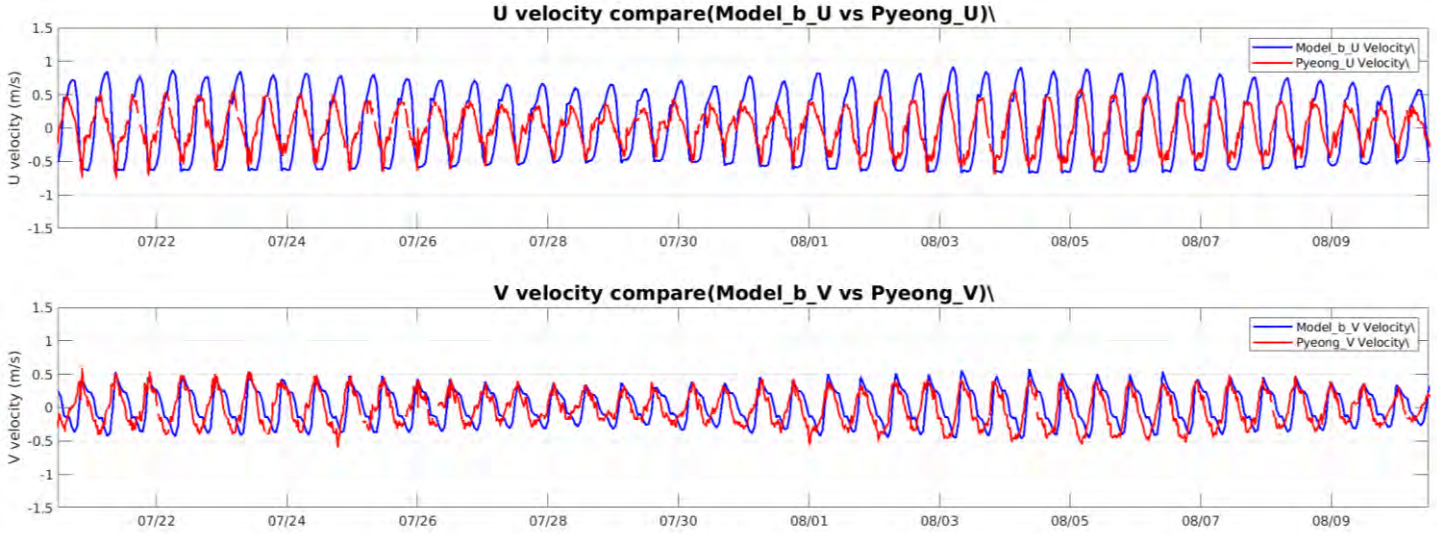
$$\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

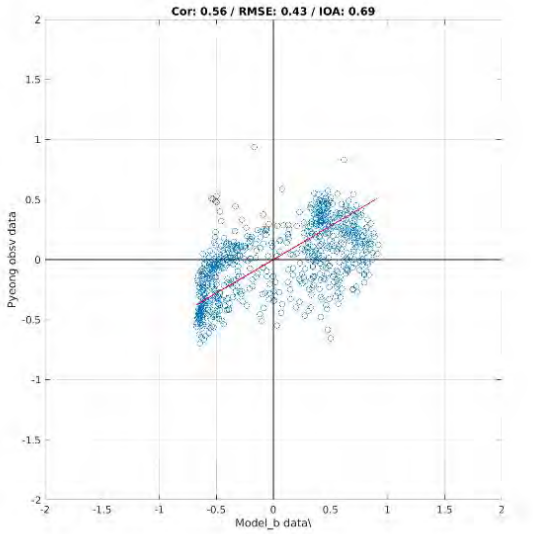
Five days video of current and temperature from Level 3 model



- Due to the wet dry, dry cell shows no value(especially in front of Daeiizak island)

Identify the causes of erosion

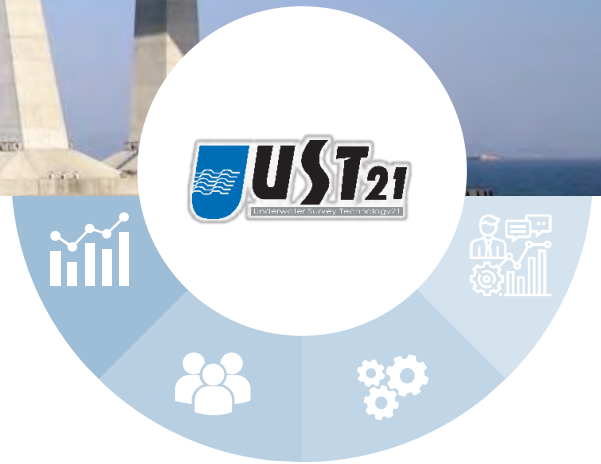




-Various bottom friction coefficients were used to match the flow velocity, and the suitable friction coefficient for Gyeonggi Bay was applied to the model

-Coupling with wave model (SWAN) is ongoing and estimate sediment transport

Thank you for your attention



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