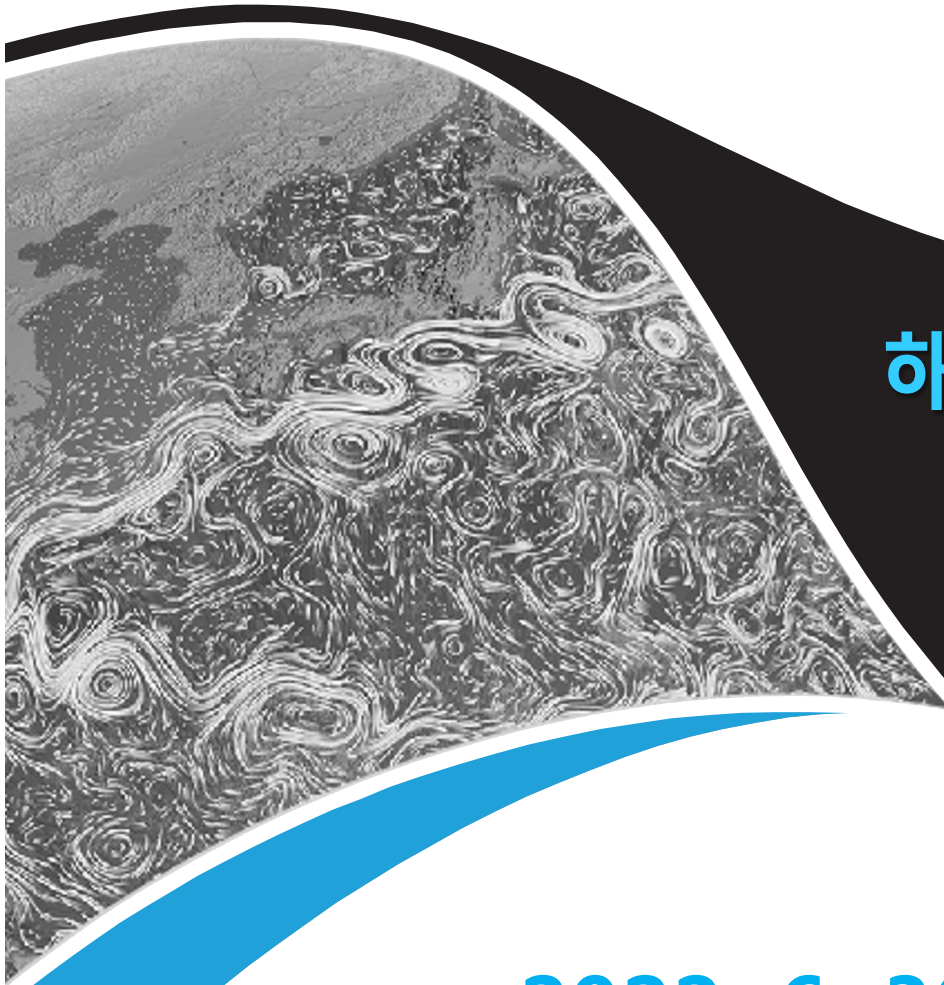


제3차

APCC 기후예측워크숍



해양자료동화 개선을 위한 해양자료의 민감도 실험

김영호, 장인성¹, 진현근², 박균도², 박영규²

¹부경대학교 지구환경시스템과학부

¹한국해양과학기술원 해양순환연구센터

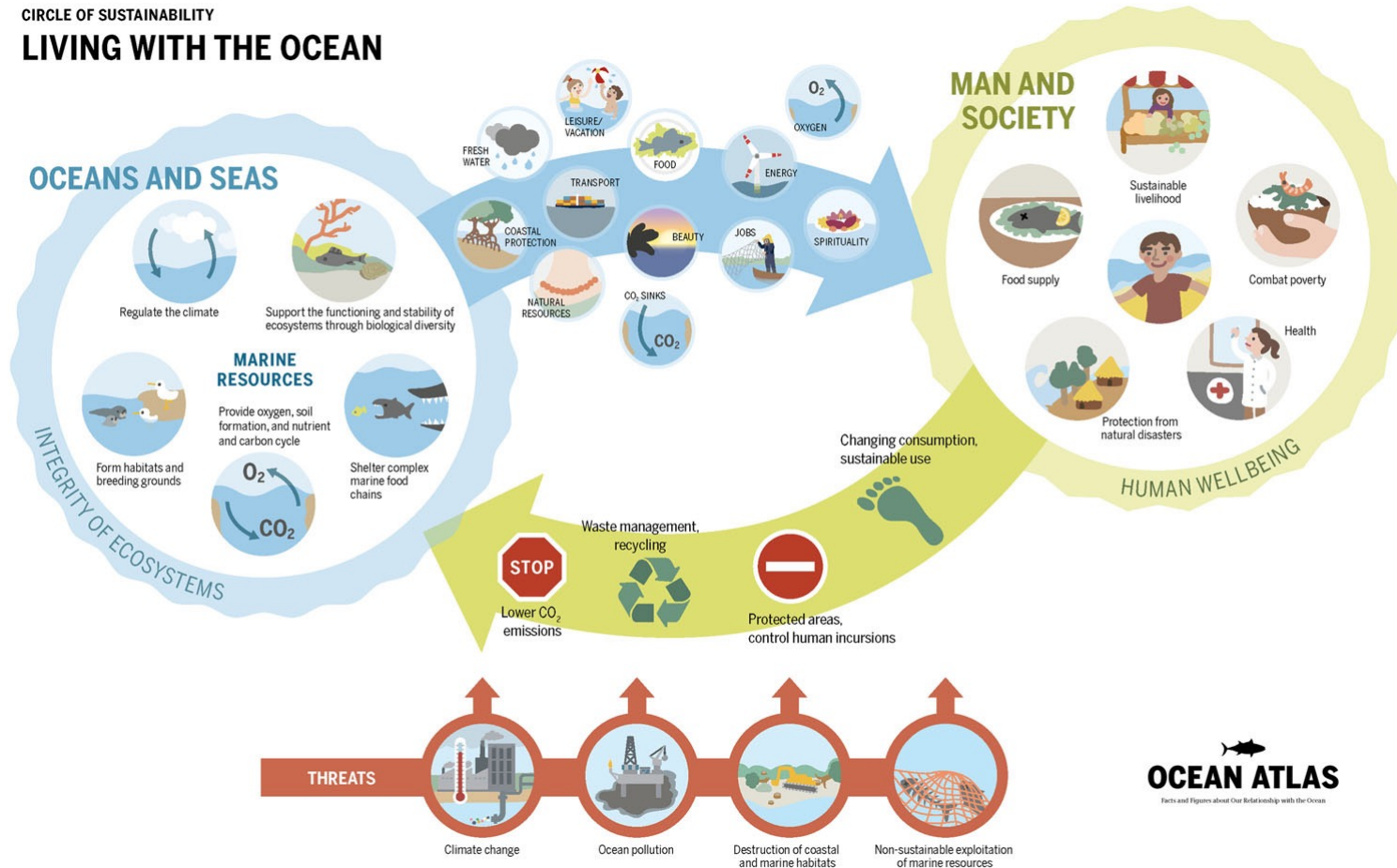
2022. 6. 30(목)



배경

CIRCLE OF SUSTAINABILITY

LIVING WITH THE OCEAN

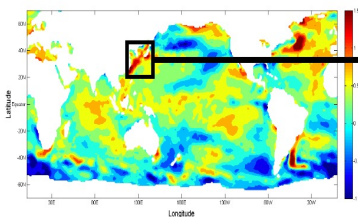


Visbeck (2018), Ocean science research is key for a sustainable future, Nature Communications

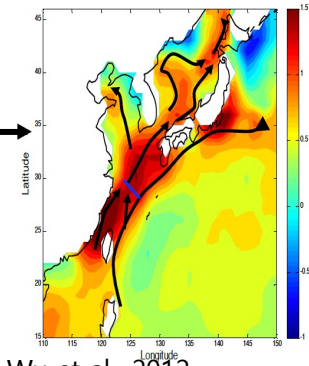
배경 - 기후 변화

The SST Trend in the Past 30 years

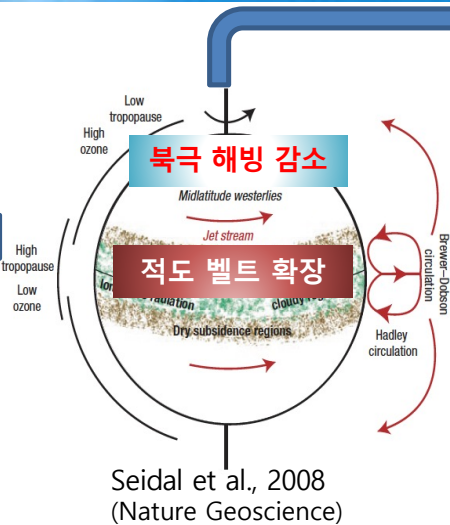
Hadley SST Trend (1970-2000)



해면수온 증가

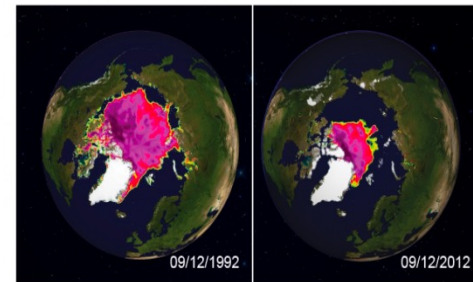


Wu et al., 2012
(Nature Climate Change)



Seidal et al., 2008
(Nature Geoscience)

Arctic Sea Ice Decline

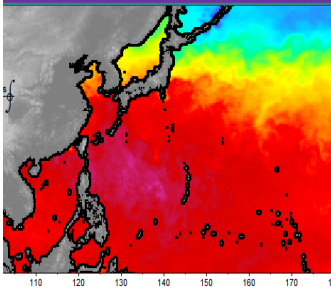


Sea Ice Concentration (%)
0 20 40 60 80 100

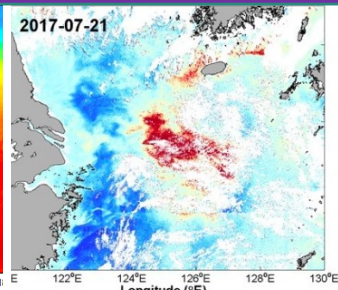
북극 해빙 감소

중위도 기후변동성 증가

2017년 이상고온



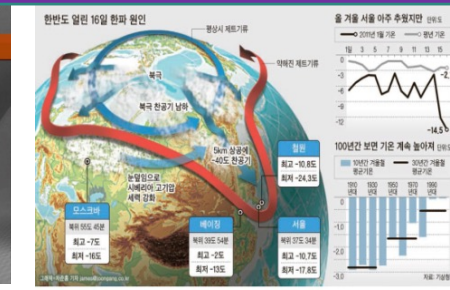
2017년 저염수 확산



2016년 여름 폭염



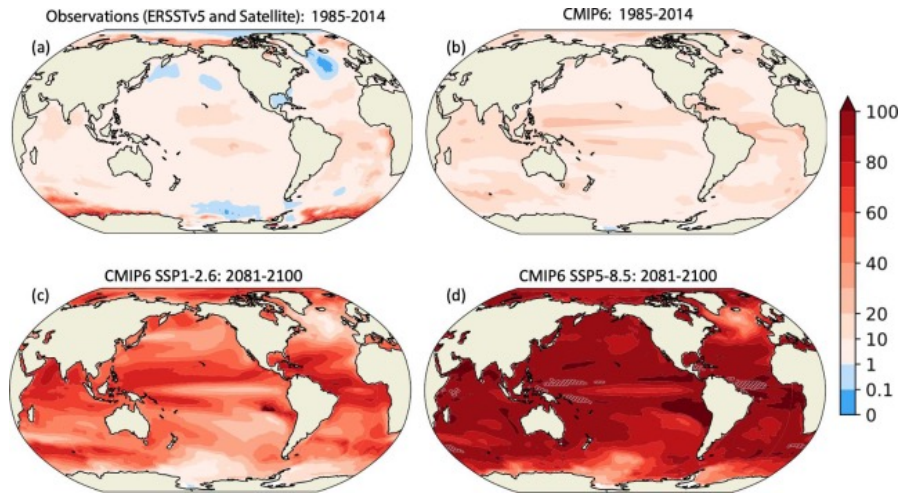
북극 한파



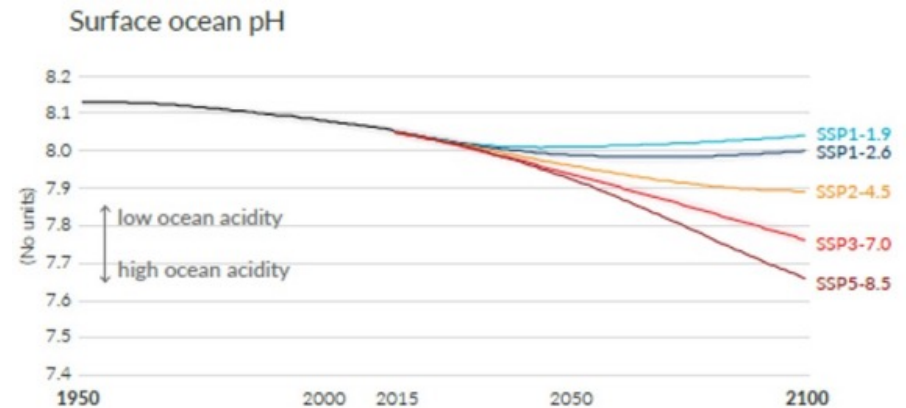
동해안 해안침식



배경 - 해양기후 변화

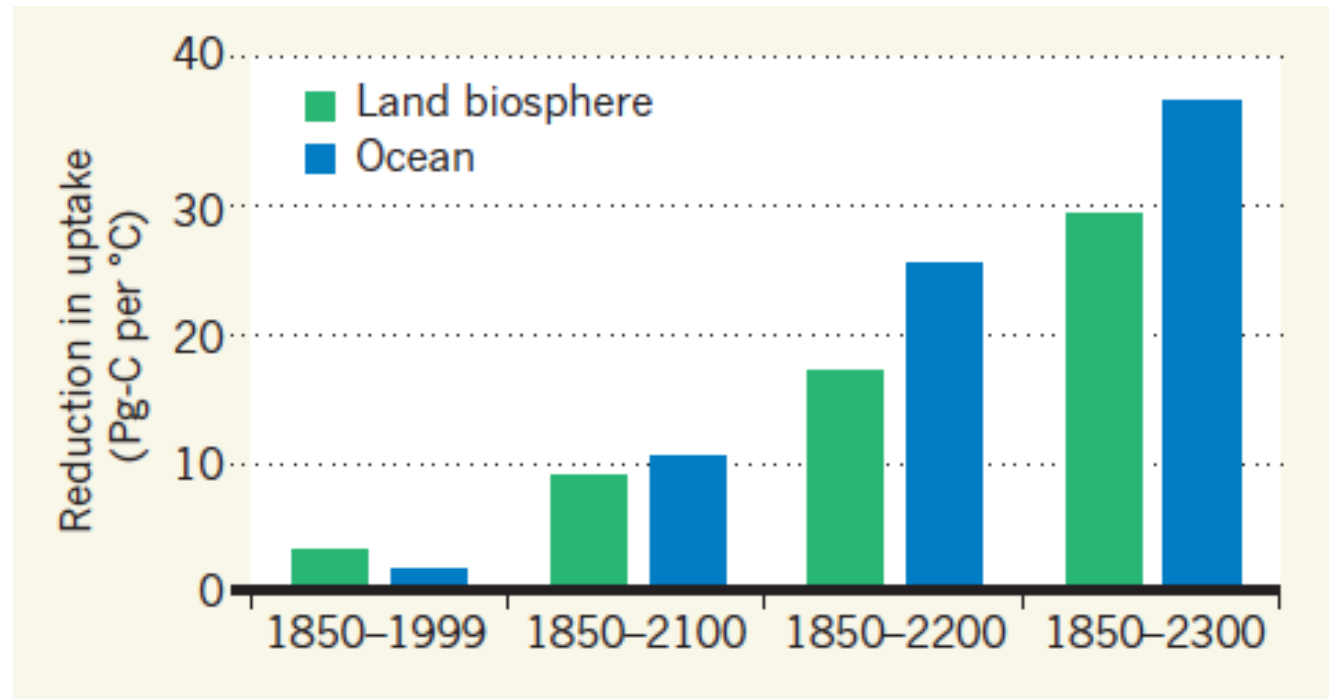


이상고수온의 발생 빈도
(IPCC AR6, 2021)



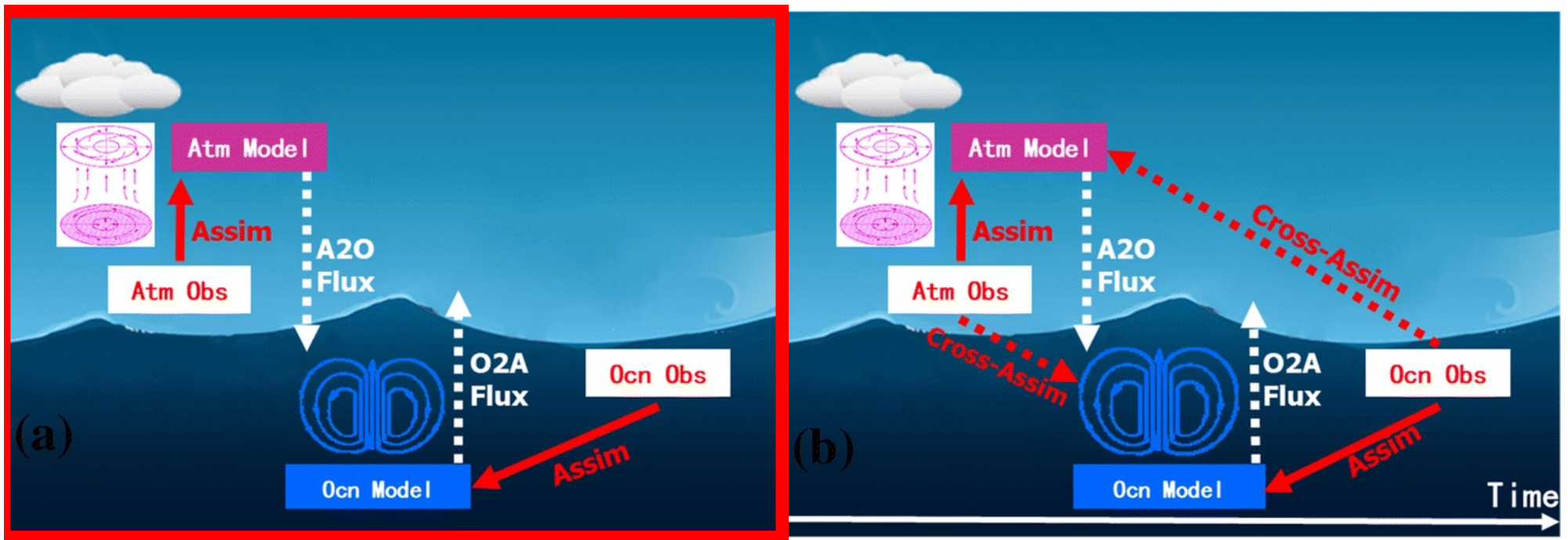
해양 표층 pH 변화
(IPCC AR6, 2021)

배경 - 기후 변화



기후와 탄소순환의 되먹임 과정에 의한 탄소흡수량을 지면과 해양으로 구분하여 나타냄 (Joos 2015)

초기화 - 결합 초기화

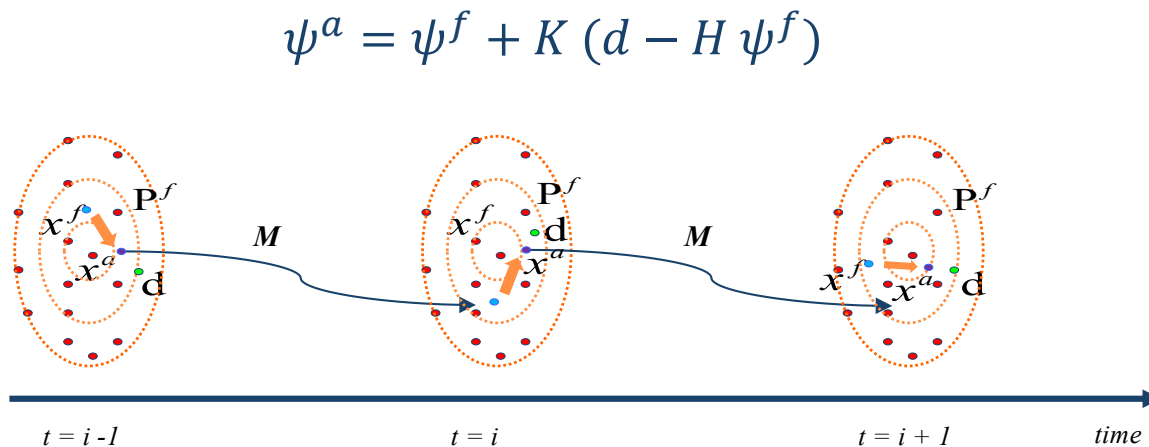


Weakly coupled data assimilation

Strongly coupled data assimilation

자료동화 – 해양초기화

- ✓ Title : DASK (Data Assimilation System of KIOST) (Kim et al., 2015)
- ✓ Method : Ensemble Optimal Interpolation (EnOI)
- ✓ Horizontal influence length scale : 300km
- ✓ Vertical influence length scale : 100m
- ✓ Target variables : SST (every day), Along-track altimetry (every day), TS profile (every week)



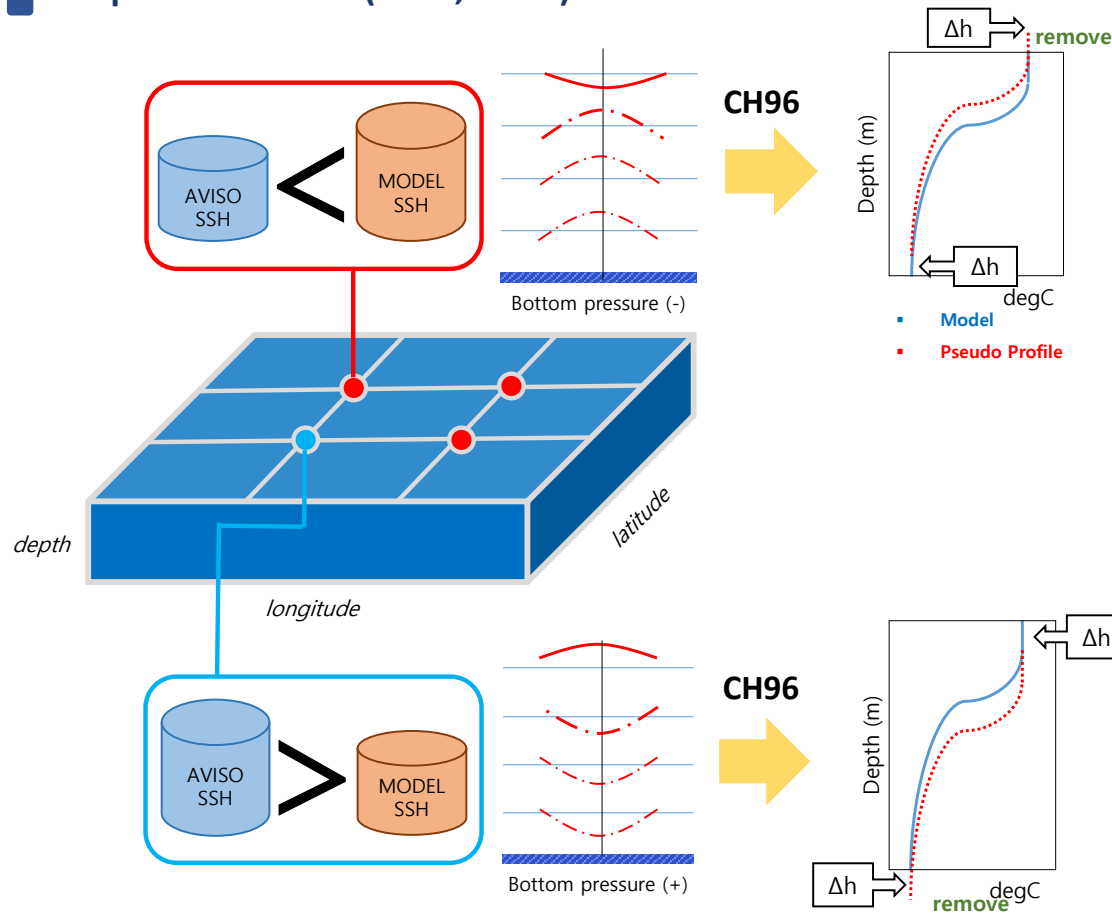
Where ;

- $\psi^a =$ Analysis fields
- $\psi^f =$ Simulated fields
- $K =$ Kalman gain
- $d =$ Observations
- $H =$ Spatial operator converting from the model data to observations

자료동화 – 해양초기화

- 위성관측 해면고도 자료동화 기법 개발
- 해면고도 -> 수온, 염분, 해류 개선

Cooper and Haines (1996, CH96)



- A) Assuming bottom pressure conservation
- B) Conservation of Potential vorticity

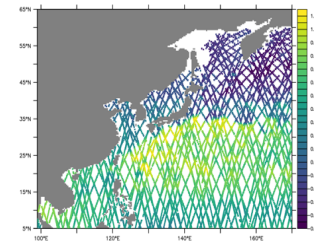
Bottom constraint

$$g \int_0^{-H} \Delta \rho dz = \Delta Ps$$

$$\Delta Ps = \rho_0 g \Delta \eta$$

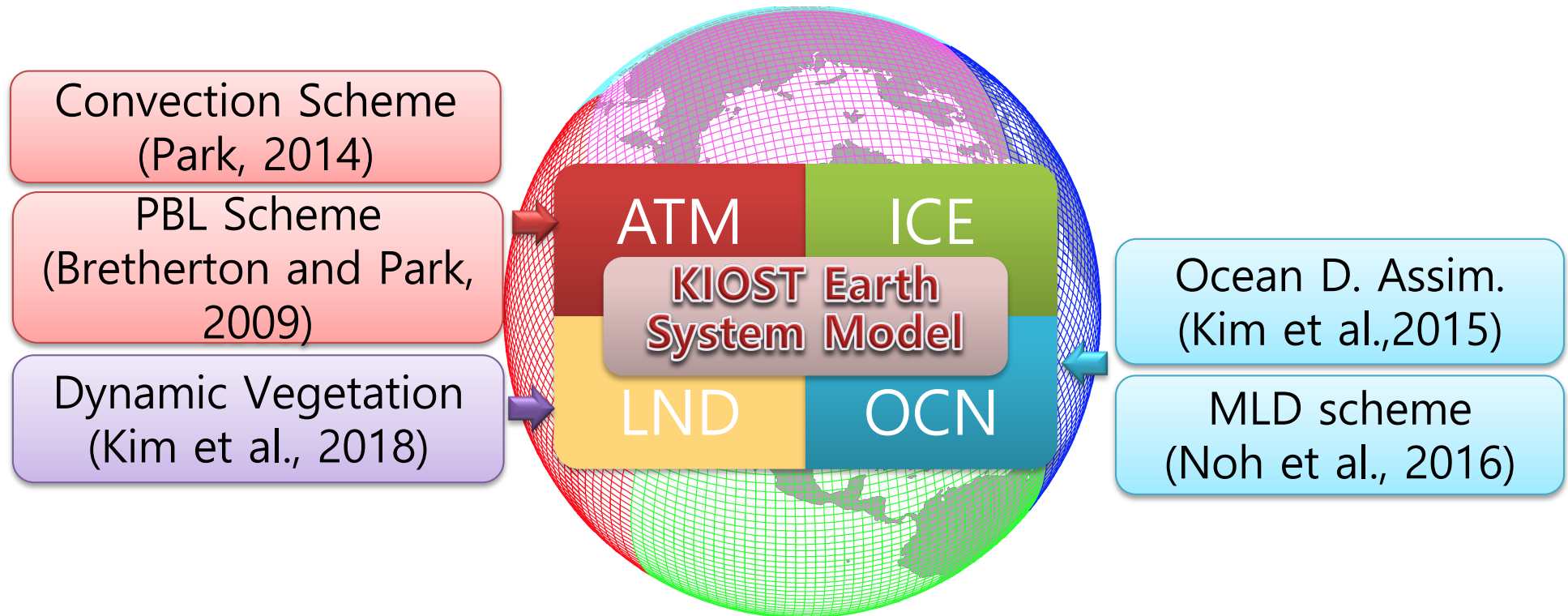
$$\Delta h = \frac{\Delta Ps}{g[\rho_0 - \rho(-H)]}$$

- ✓ Creates a "Pseudo profile" using "Δh" and the "model's profile" at the specific grid points



자료동화 - 기후초기화 시스템

Framework adopted from GFDL CM2.5 → Applying new physics
Some of them have been newly developed



KIOST 가이아 연구 프로젝트 (2009-2019, 연구책임자: 이재학)



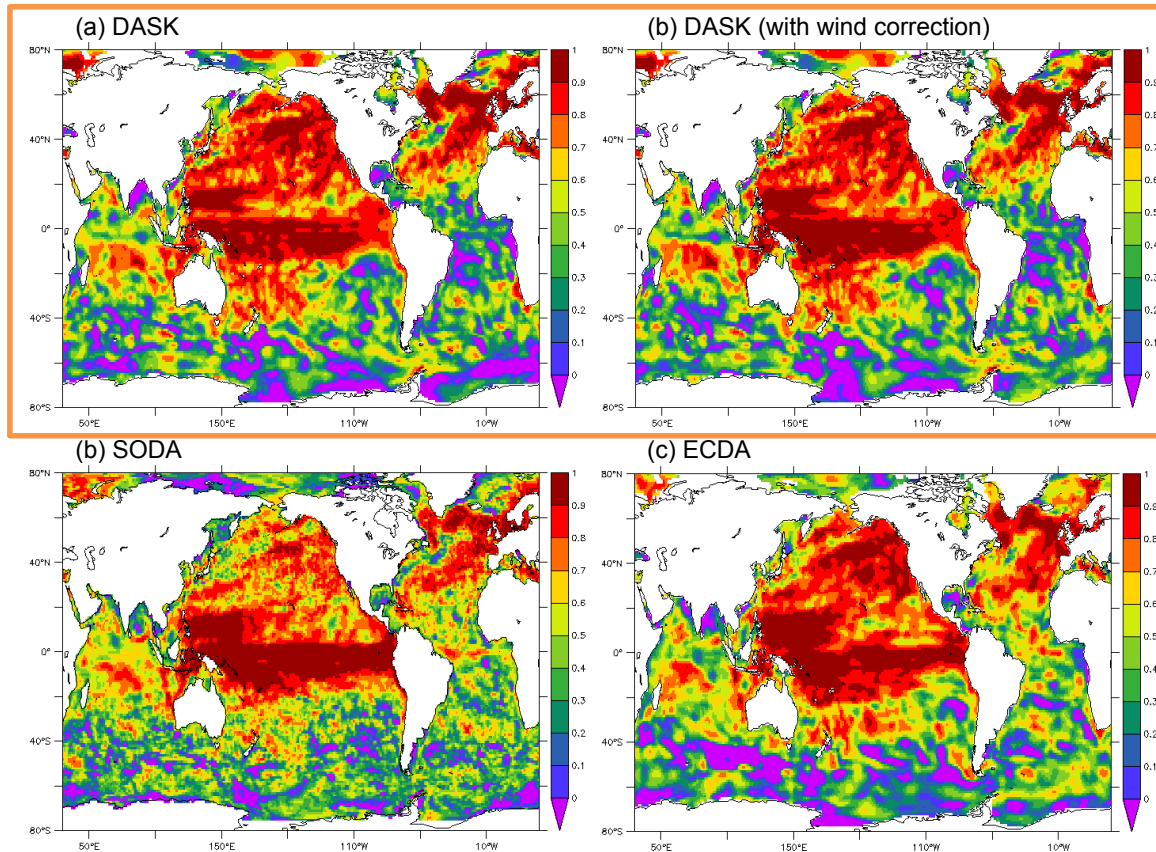
UNIST



국립부경대학교
PUKYONG NATIONAL UNIVERSITY

자료동화 – 기후재분석 자료

◆ 해양열용량 비교(관측과의 상관계수)



DASK	DASK+wind
SODA	ECDA

APDRC Datalog: 1 Data Assimilation System of KIOST (Korea Institute of Ocean Science & Technology) 13/08/2014 5:29 am



Home | New | Data | Partners | Projects | Servers | Tutorials | IPRC

Data Assimilation System of KIOST (Korea Institute of Ocean Science & Technology)

KIOST has developed an ocean data assimilation system to be cooperated with a coupled climate model. The main goal of the Data Assimilation System of KIOST (DASK) is to produce the best estimation of the ocean state.

The DASK has been developed based on the Ensemble Optimal Interpolation applied to the GFDL's fully coupled climate model (CM2.1, Delworth et al. [2006]). The ocean component model is the fourth version of the Modular Ocean Model (MOM4, Griffies et al. [2004]). The ocean model has horizontal resolution of 1° in latitude and longitude, with meridional resolution becoming finer equatorward from 1° at 30° to 1/3° at equator, and 50 vertical levels. The assessment by comparison with other global reanalyses suggests that the DASK well represents ocean climate variability, for example, El Niño Southern Oscillation, North Pacific Intermediate Water, Pacific Decadal Oscillation, Indian Ocean Dipole in spite of low consumption of computing resource. For more details, please see their website (<http://las.kiost.ac.kr/las/UI.vm>). DASK 1.4 : Monthly mean in 1947-2012.

Publication
Kim, Y.H., C. Hwang, W.-M. Kim, Development and validation of KIOST Climate Reanalysis, Proceedings of 2014 Ocean Science Meeting.

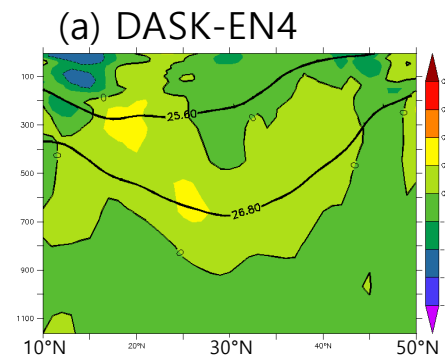
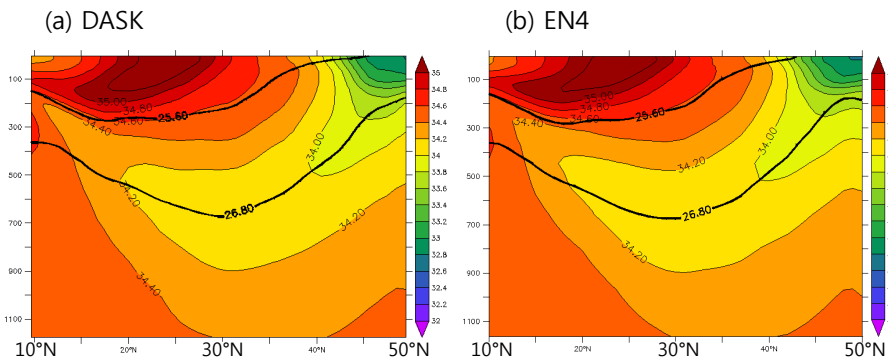
Kim et al. (2015)

자료동화 – 기후재분석 자료

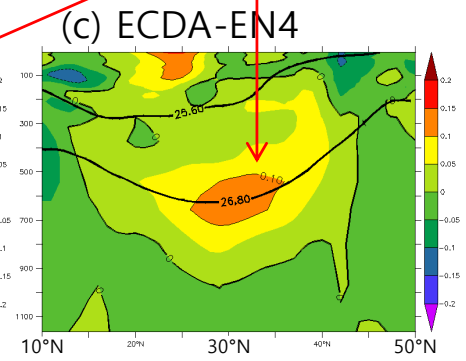
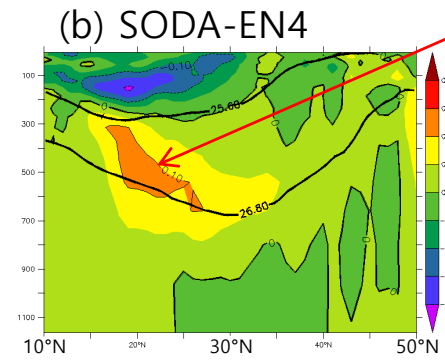
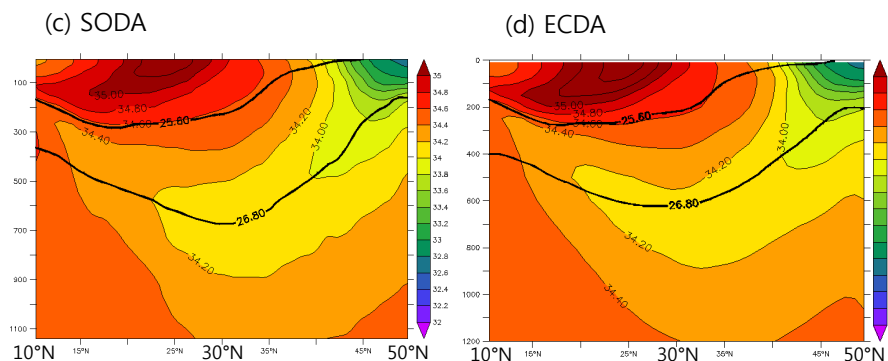
◆ North Pacific Intermediate Water

- ✓ Salinity minimum layer water in the North Pacific
- ✓ Major factor in determining the long-term variability of the North Pacific

DASK	Observation
SODA	ECDA



High Salinity Bias



Meridional section of salinity along the dateline

Meridional section of salinity difference from the obs. along the dateline

Kim et al. (2015)

기후변동성 진단 - 해양초기장 중요

기후재분석(자료동화) -> 기후 진단

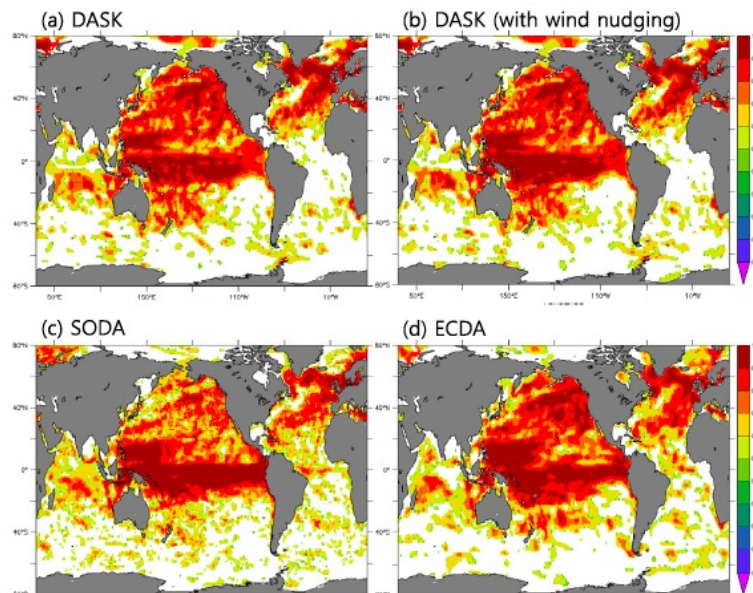


Fig. 13. Horizontal map of correlation coefficient between upper HC300 estimated from EN4 and modeled HC300 (from 1980 to 2010) for (a) DASK, (b) DASK with wind correction, (c) SODA and (d) ECDA. The regions, where the correlation is lower than 99% confidence level, were shaded in white. Anomalies to calculate the correlation coefficient are relative to the climatology of the period and 1-year running mean has been applied.

Kim et al. (2015)

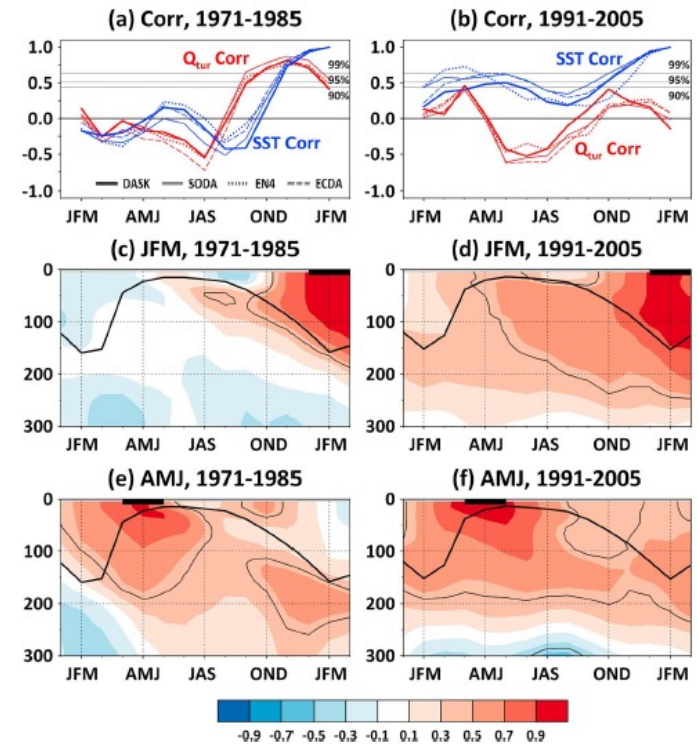


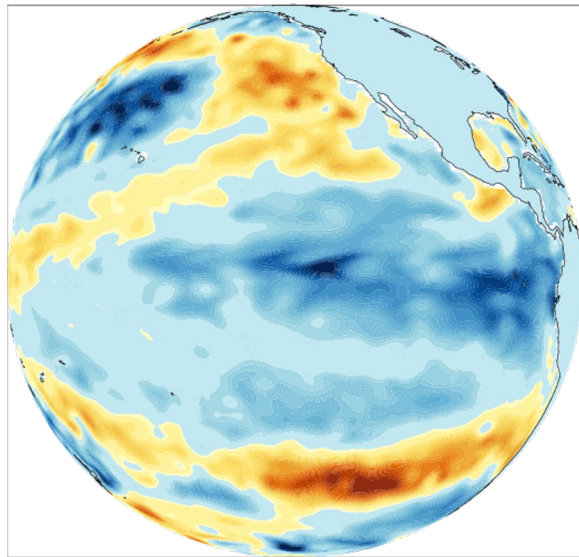
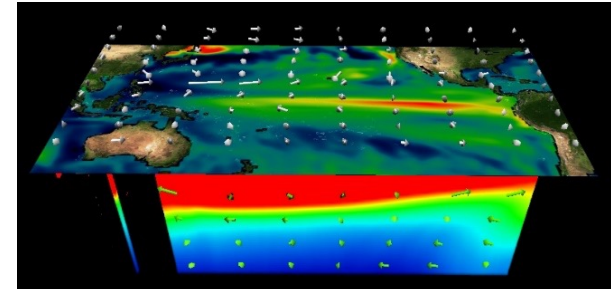
Figure 2. (a, b) Correlation coefficients of JFM SST with 3-month averaged Q_{tur} (red) and SST (blue) during (a) 1971-1985 and (b) 1991-2005 in the Kuroshio recirculation gyre region. Sources of SST data are indicated. Confidence intervals at 90%, 95%, and 99% are marked with gray lines. (c-f) Lead-lag correlation coefficients of temperature as a function of season (x axis) and each depth (y axis, m) with (c, d) JFM SST and (e, f) preceding AMJ SST during (c, e) 1971-1985 and (d, f) 1991-2005 overlaid with mixed layer depth and significant correlation at 90% confidence level marked with thick and thin solid contours, respectively. SST = sea surface temperature; JFM = January-March; AMJ = April-June; JAS = July-September; OND = October-December.

Pak et al. (2019)

해양초기화 - 기후예측

기후예측 시스템

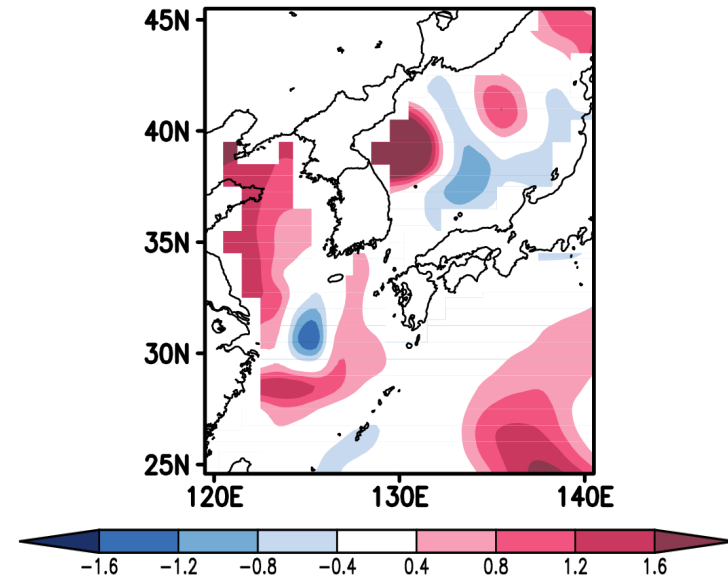
엘니뇨 예측



KIOST Climate Reanalysis

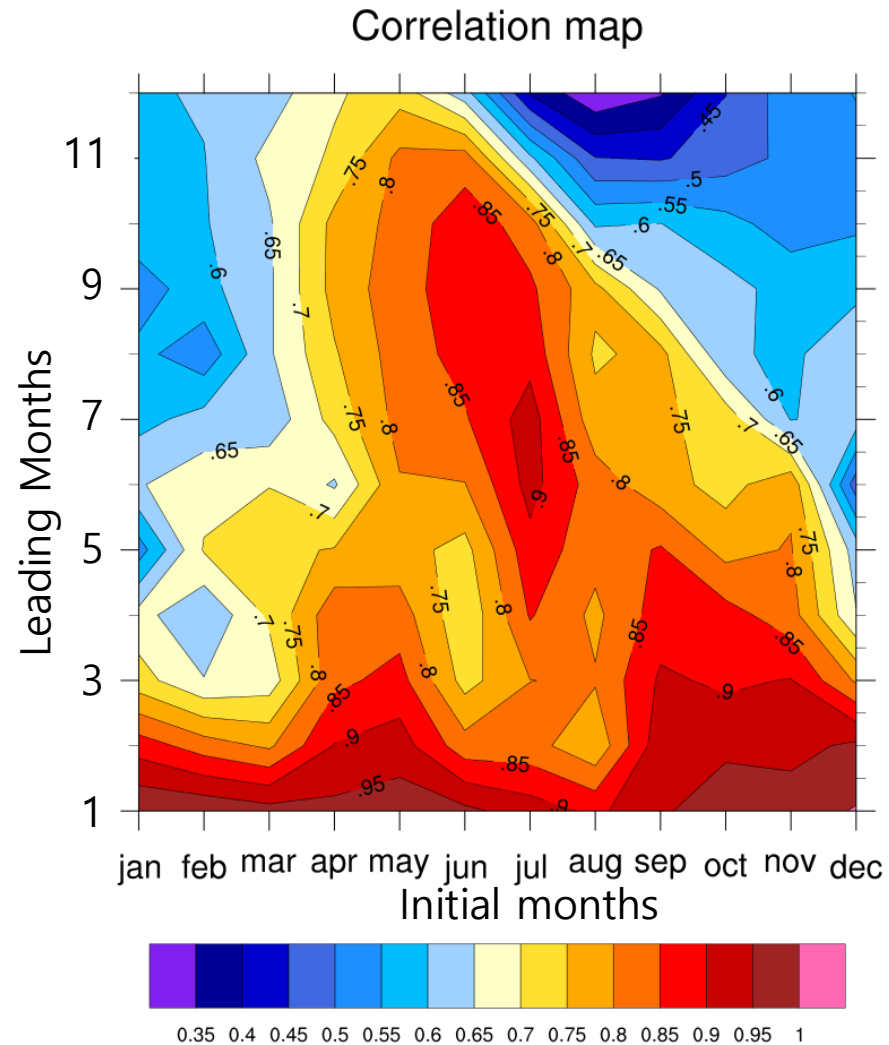


한반도 기후 예측 (해수온)



해양초기화 - 기후예측

- KIOST 기후재분석자료를 초기장으로 기후예측시스템 개발
- 엘니뇨 시범 예측 수행

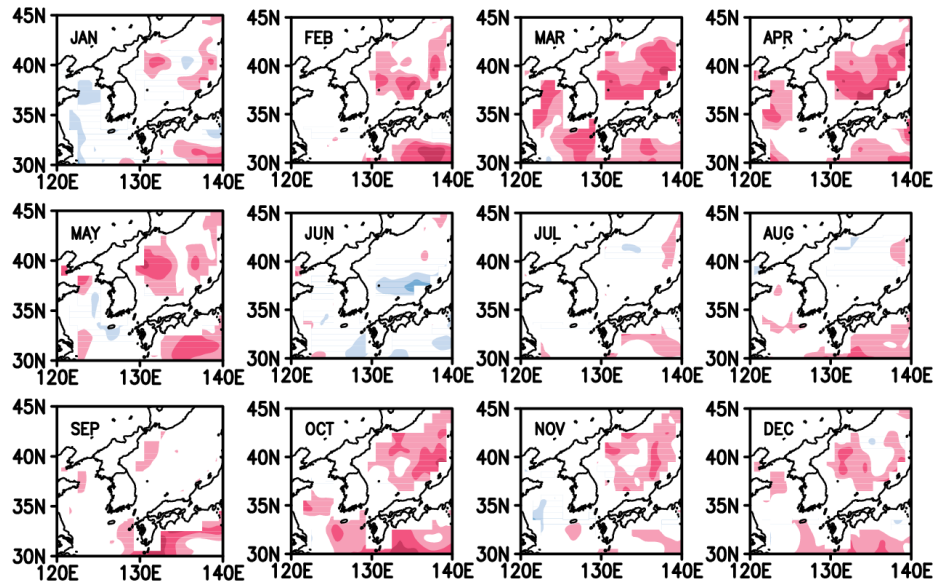


해양초기화 - 기후예측

- 월마다 차이는 있으나 봄철의 역학모형 성능이 좋음
- 미국 CFS와 비교: 비교할만 하지만, KIOST 역학모형의 성능은 특히 2-3월이 좋지 않음

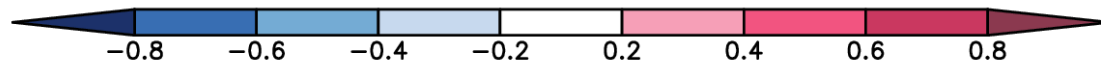
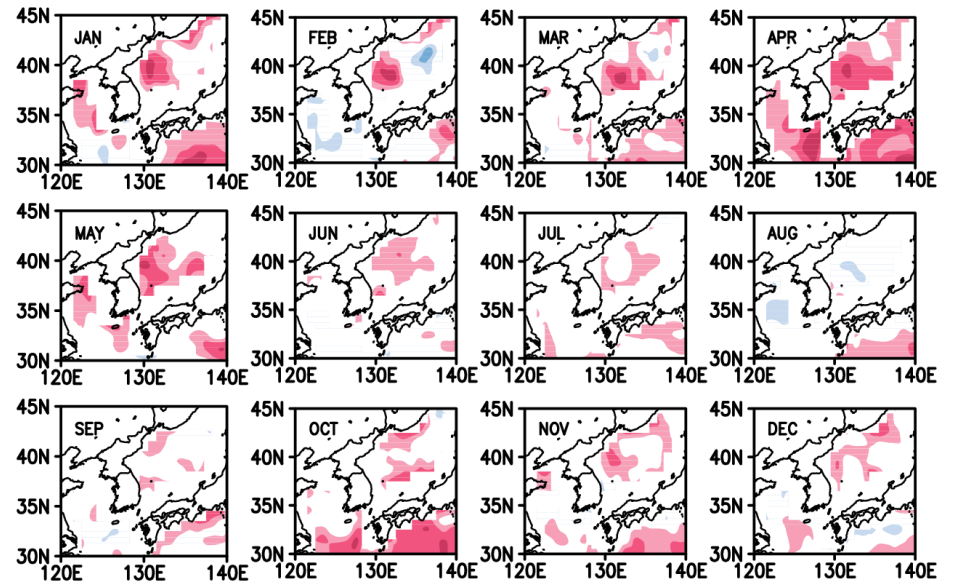
미국 현업기관 모형의 예측성

COR(TMP_{5m}, CFS-SODA3.4.2)



KIOST-ESM 의 예측성

COR(TMP_{5m}, DASK-SODA3.4.2)



관측자료 민감도 실험

Observation System Simulation

Table 1. Experimental design

	Control variables	Assimilation period
CTR	Free run	1 year (1993.01.01.~1993.12.31.)
EXP01	SST	
EXP02	SST, T/S profile-KODC	
EXP03	SST, T/S profile+KODC	
EXP04	SST, T/S profile - KODC, SSH	
EXP05	SST, T/S profile +KODC, SSH	

Model domain and Bottom Relief

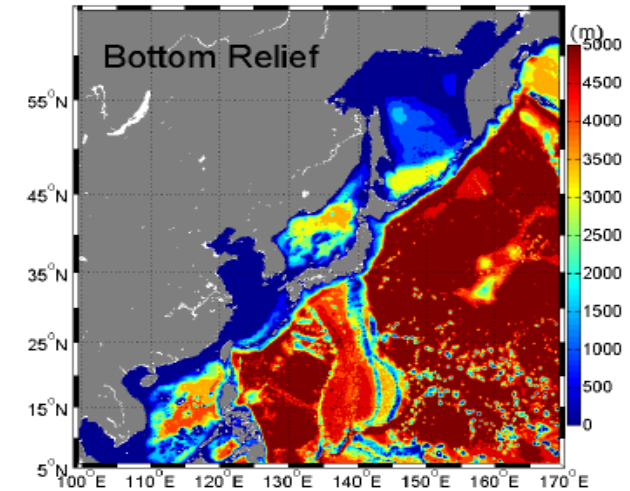


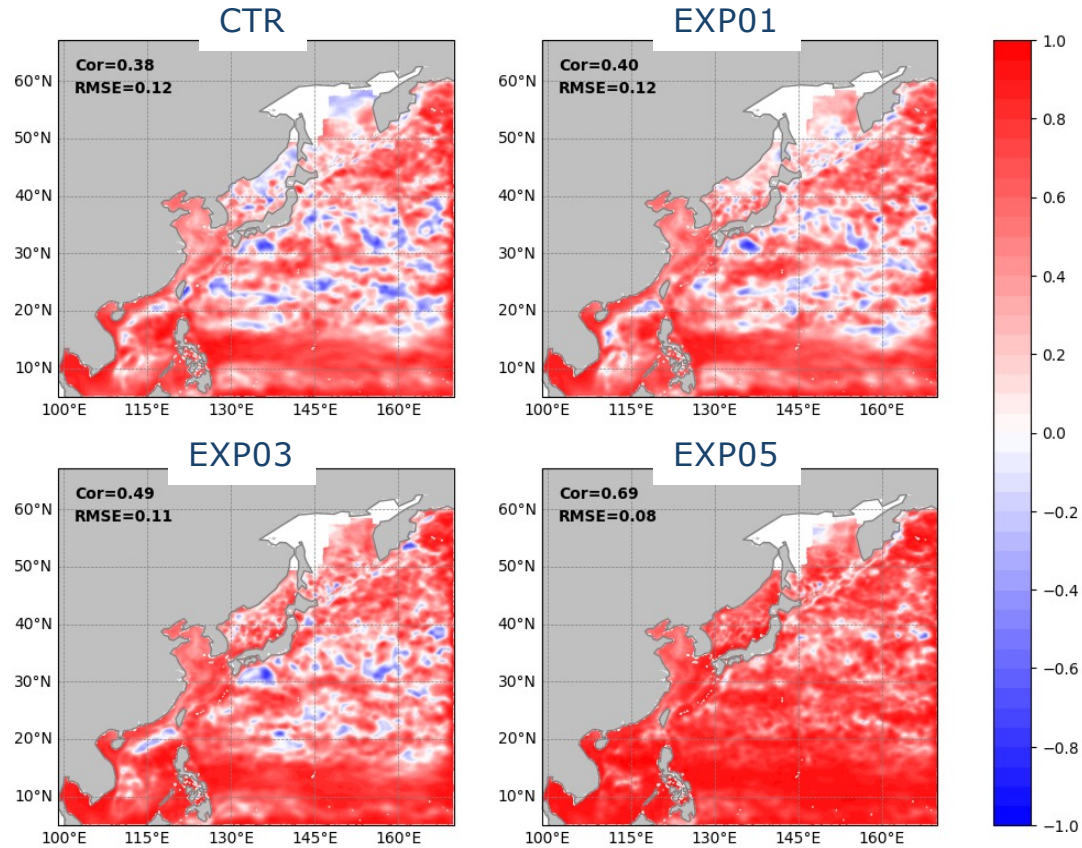
Table 2. observation dataset and data source using assimilation

	Dataset and Source	Assimilation interval
T/S profiles	World Ocean Database 2018 (OSD,CTD,XBT,MRB)	Every 7 days
	Korea Oceanographic Data Center (KODC)	
SST	Optimum Interpolation Sea Surface Temperature (OISST) v2	Every day
SSH	CMEMS - GLOBAL OCEAN ALONG-TRACK L3 SEA SURFACE HEIGHTS REPROCESSED(1993-ONGOING) TAILORED FOR DATA ASSIMILATION (Topex/Poseidon, ERS-1)	Every day

Table 3. Validation dataset

Variables	Dataset
T/S profiles	World Ocean Database 2018 (OSD,CTD,XBT,MRB) KODC
SSH	CMEMS-GLOBAL OCEAN GRIDDED L4 SEA SURFACE HEIGHTS AND DERIVED VARIABLES REPROCESSED (1993-ONGOING)
Velocity	Ocean Surface Currents Analyses Real-time (OSCAR, 2009), 1/3°

관측자료 민감도 실험 결과

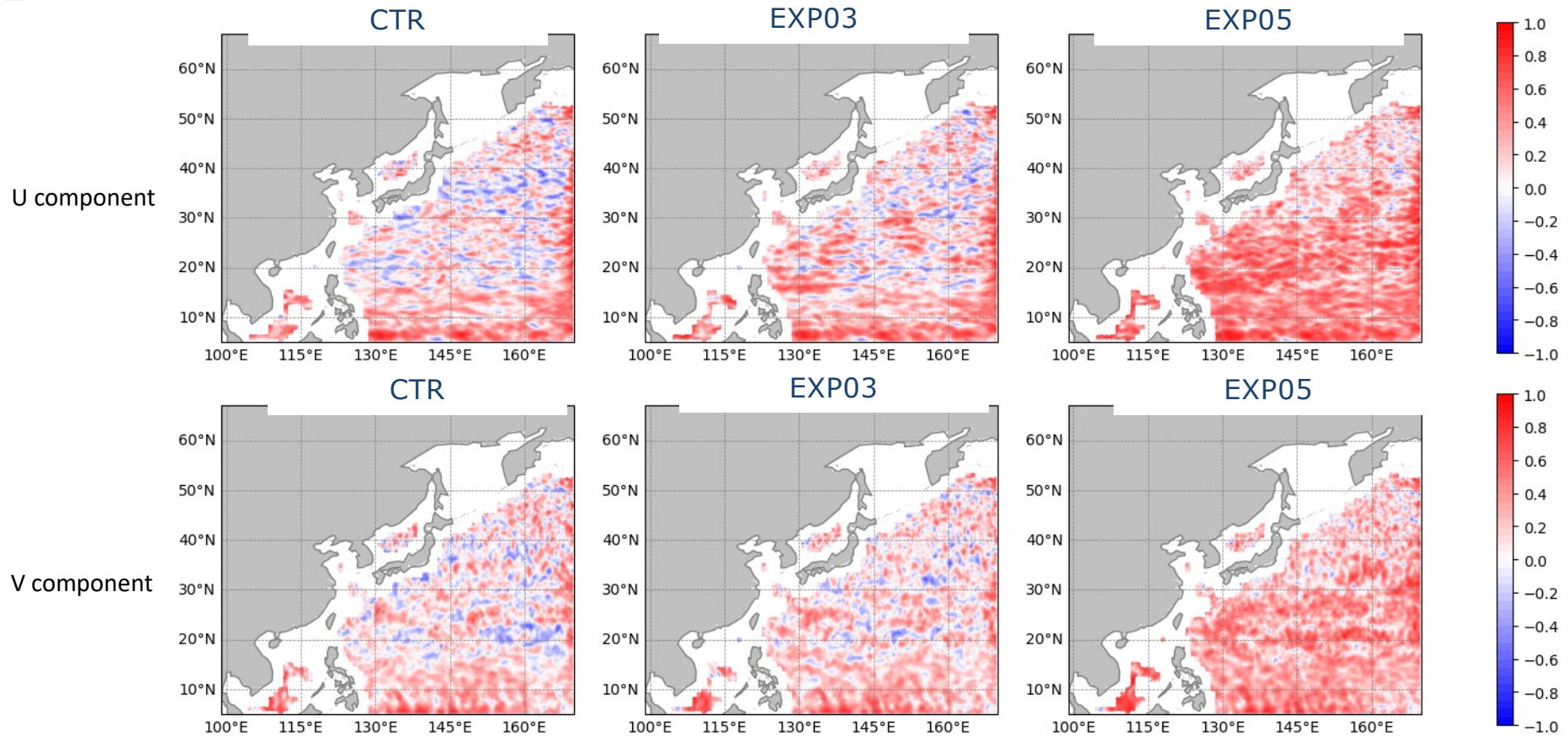


- Spatial distribution of correlation coefficient for SSH with respect to AVISO gridded data.

관측자료 민감도 실험 결과

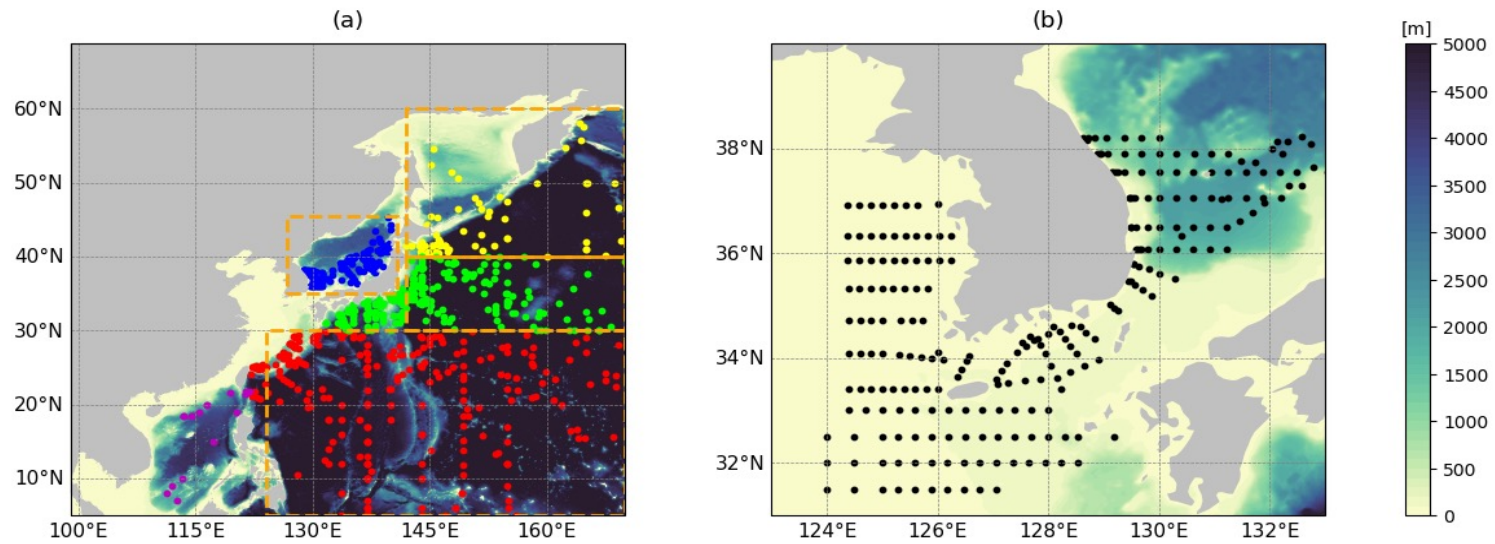
- 해면고도 자료동화를 통한 해양 초기장 개선
- 특히, 해류장 개선

Spatial correlation of ocean surface current with respect to observation

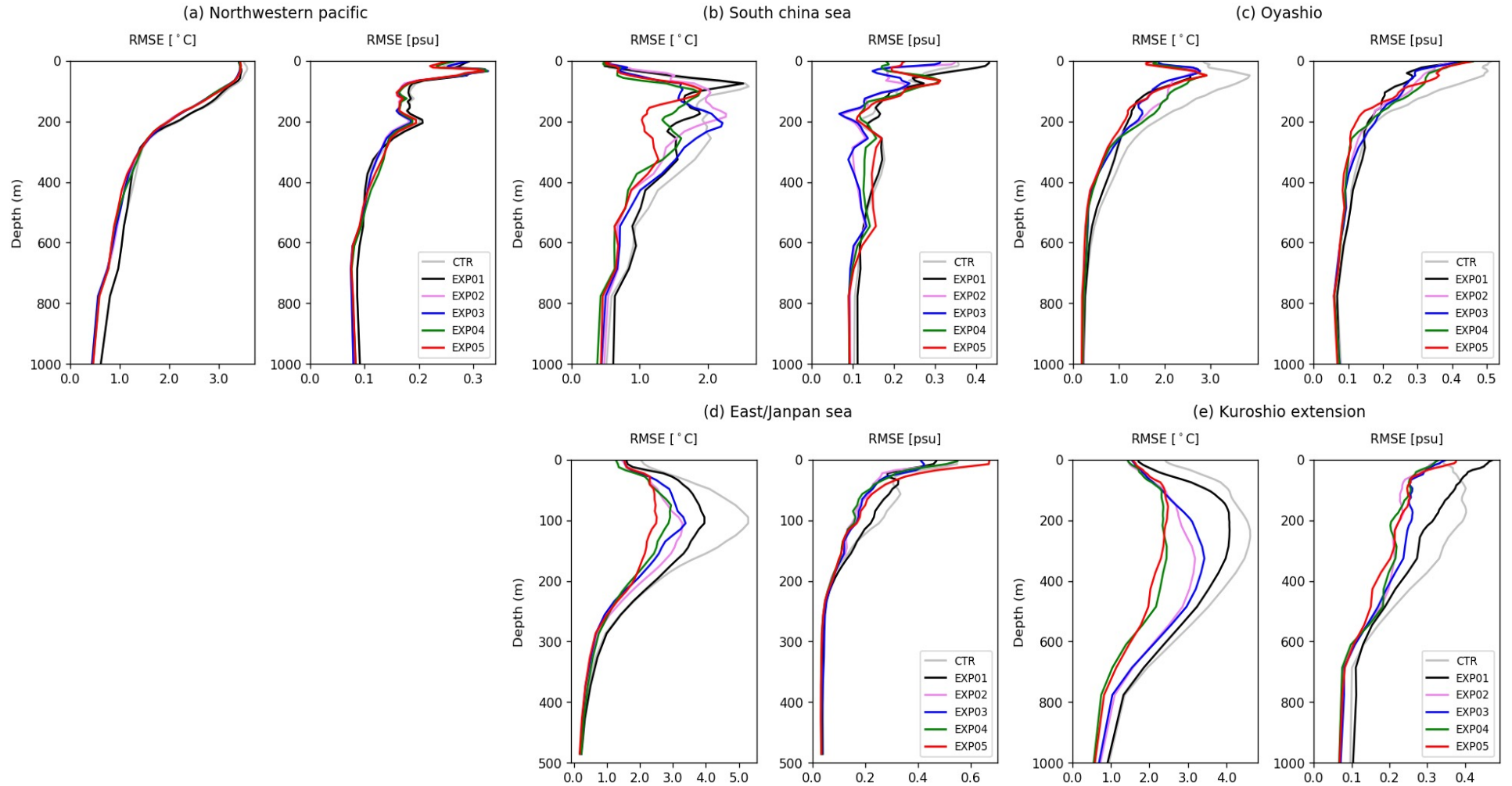


✓ The correlation of ocean surface current with respect to observation are also improved through this indirect assimilation system

관측자료 민감도 실험 결과



관측자료 민감도 실험 결과

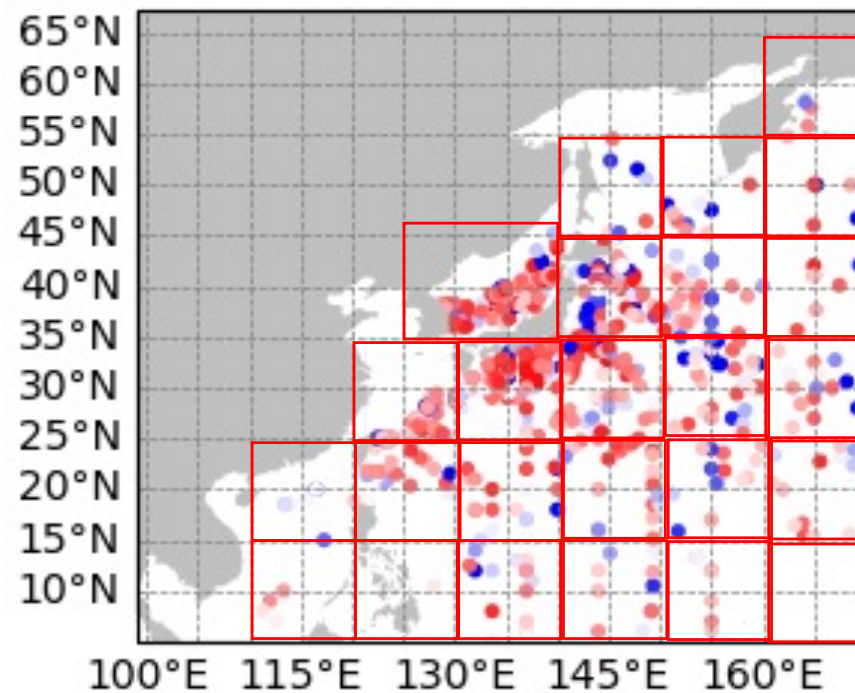


관측자료 민감도 실험 결과

$$RMSE = \sqrt{\frac{1}{m} \sum_{i=1}^m (Observation_i - Analysis_i)^2}$$

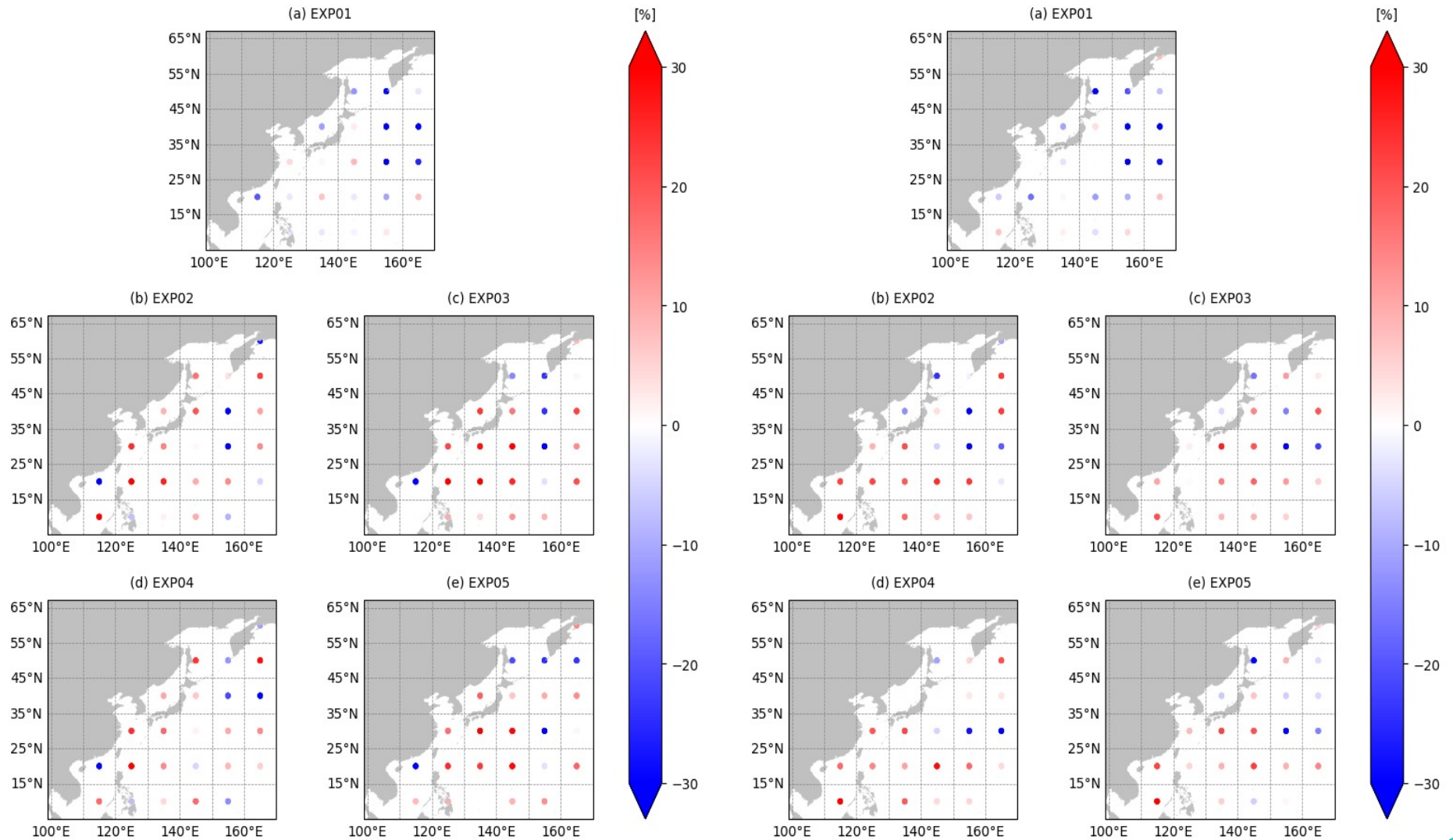
$$Impact\ of\ data\ assimilation\ (IOA) = \frac{RMSE_{CTR} - RMSE_{EXP}}{RMSE_{CTR}}$$

(e) EXP05



관측자료 민감도 실험 결과

Mean IOA (100~500m)



Temperature

Salinity

요약

□ 해양초기화 적용

- 지구시스템 모형 + 약한 결합 자료동화 (Weekly Coupled DA)
- 기후재분석 자료 -> 기후변화 진단
 - 해양-대기 상호작용의 변동
 - 해양초기화에 따른 기후예측 성능 변화 가능성
- 해양초기화에 따른 기후예측 가능성
 - 엘니뇨 시범 예측 수행
 - 한반도 계절 예측 수행

요약

□ 해양자료동화 민감도 실험

- SST, Profile, SSH 와 한반도 주변 관측망에 대한 해양초기장 민감도 실험 수행
- SSH 동화에 따른 해류장 개선
- KODC 프로파일 자료의 민감도 확인
 - 동해 수온-염분 개선
 - 쿠로시오, 쿠로시오 확장역 수온-염분 개선

감사합니다