OPST-8 meeting Science Day Nov. 9, 2023.

Evaluation of regional **ocean reanalysis datasets** for the **East Sea**

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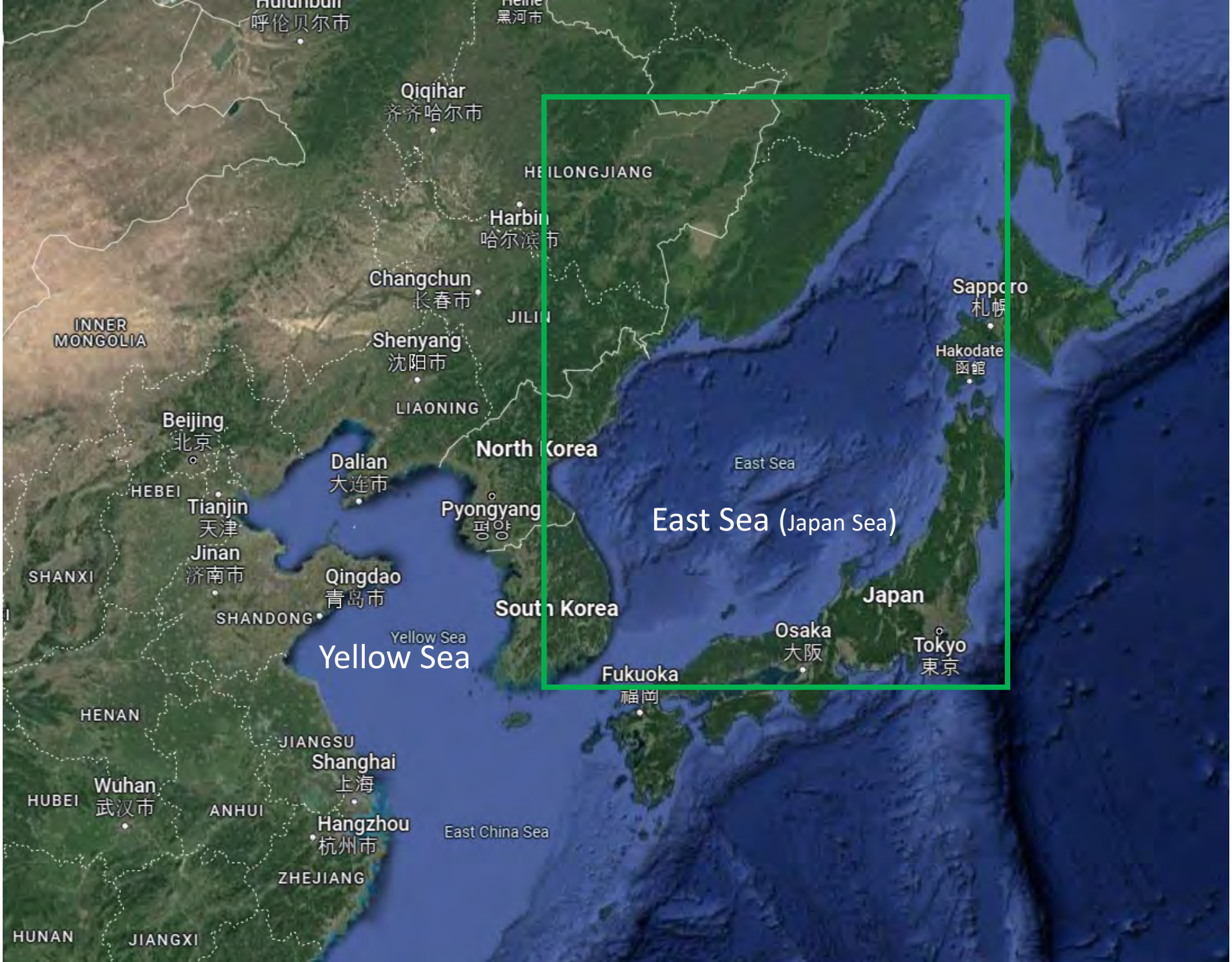
Outline

1. Introduction
2. Observation and Reanalysis **Datasets**
3. Evaluation of Ocean Reanalysis Data in the **East Sea**
   - OHC, MLD, Depth of 10℃ isotherm, Salinity,
     Steric Height, Sea Level
4. Summary

Objectives

To evaluate and intercompare **O**cean **R**eanalysis **D**ata in the **East Sea**

To understand interannual variability of the East Sea


Hulunbuir
呼伦贝尔市
Heihe
黑河市
Qiqihar
齐齐哈尔市
HEILONGJIANG
Harbin
哈尔滨市
Changchun
长春市
JILIN
Sapporo
札幌
Hakodate
函館
INNER MONGOLIA
Shenyang
沈阳市
LIAONING
Beijing
北京
Dalian
大连市
North Korea
East Sea
HEBEI
Tianjin
天津
Pyongyang
평양
East Sea (Japan Sea)
Jinan
济南市
SHANXI
Qingdao
青岛市
Japan
South Korea
SHANDONG
Yellow Sea
Osaka
大阪
Tokyo
東京
Yellow Sea
Fukuoka
福岡
HENAN
JIANGSU
Shanghai
上海
Wuhan
武汉市
HUBEI
ANHUI
Hangzhou
杭州市
East China Sea
ZHEJIANG
HUNAN
JIANGXI

Data and Ocean Reanalysis

Observation Data

EN4

WOA2018

Ocean Reanalysis Data (**2001-2020**)

HYCOM

Mercator Ocean (GLORYS12v1, MOi, CMEMS)

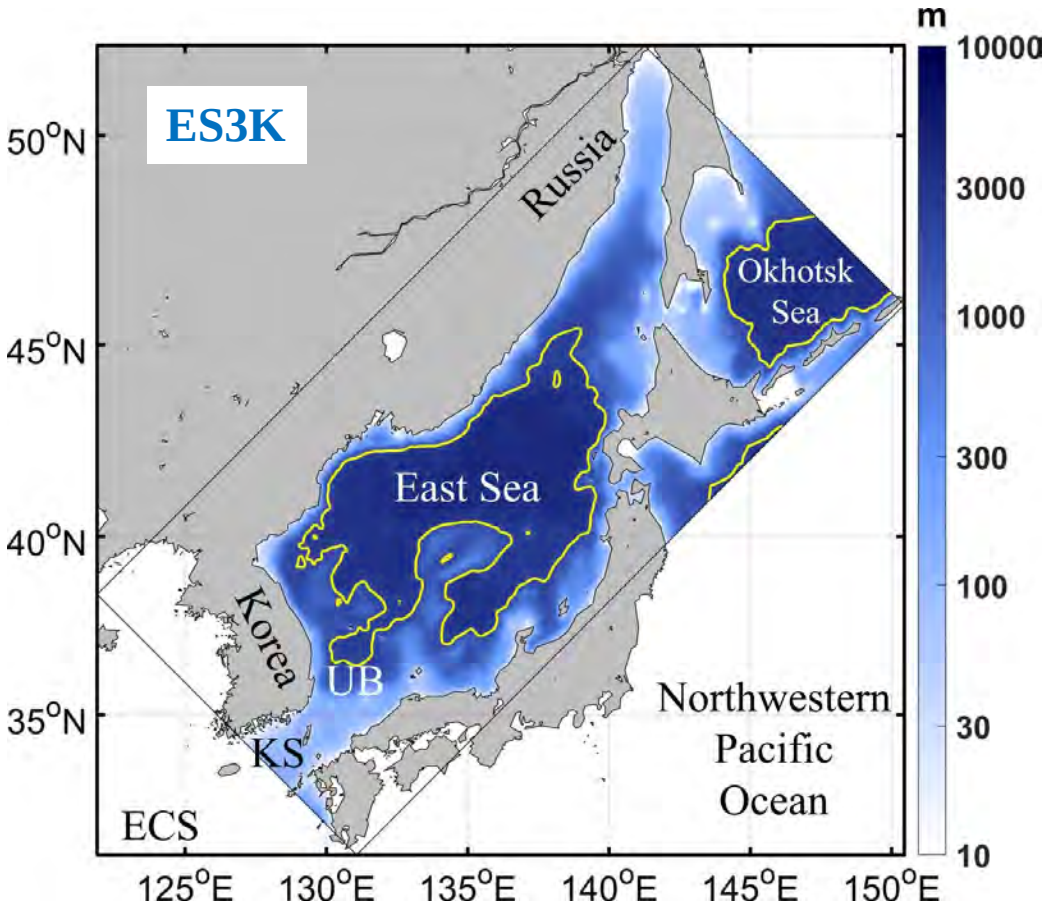
ES3K (Korea Ocean Observing and Forecasting System, KOOFS, KHOA)

Ocean Variables used for comparison

Ocean Heat Content (OHC)
Depth of 10℃ isotherm
Mixed Layer Depth (MLD)
Salinity
Steric Height
Sea Level

2. Observation and Reanalysis **Data**

Data and Ocean Reanalysis



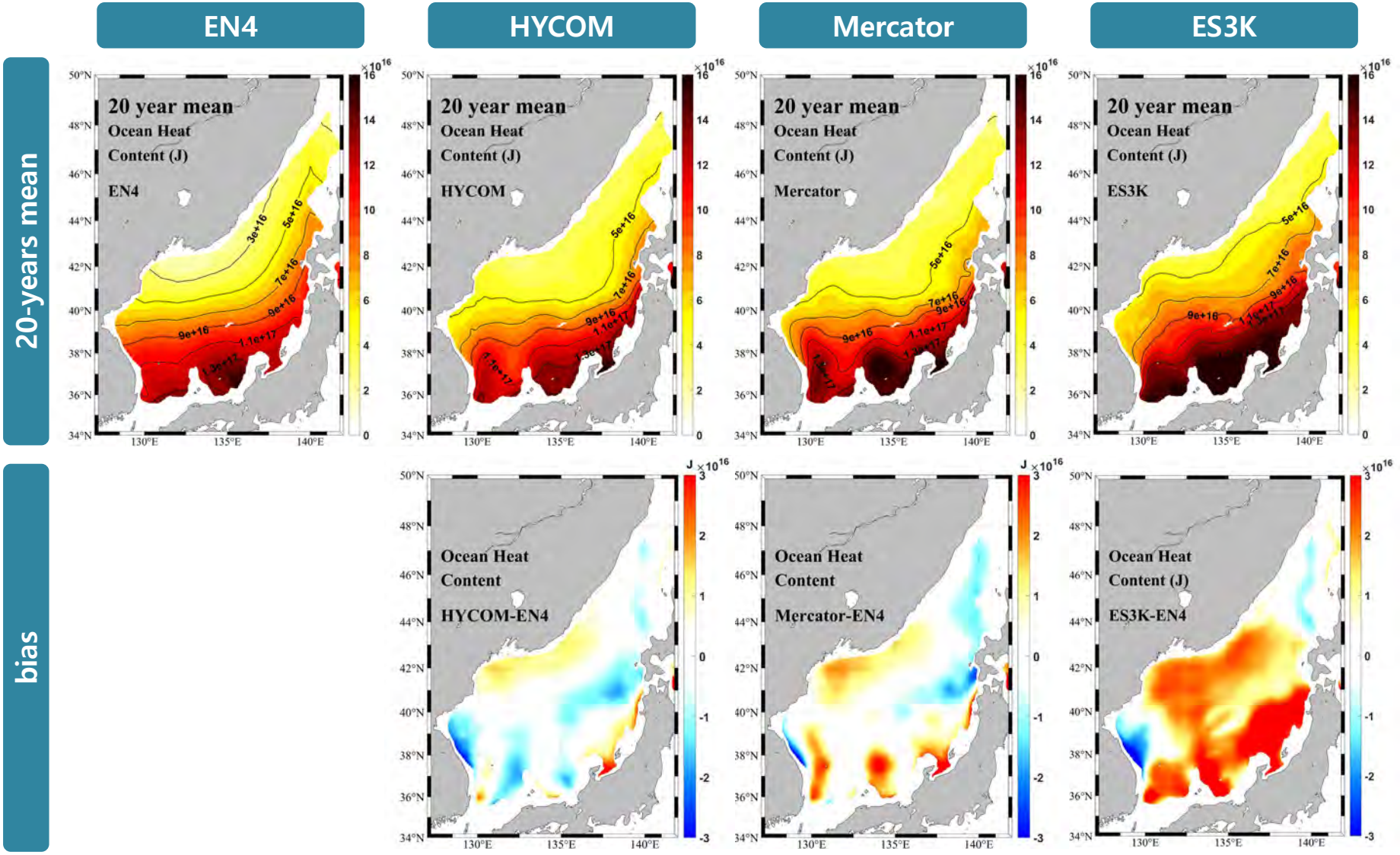
(Korea Ocean Observing and Forecasting System, **KOOFS**, KHOA)

Model: ROMS
Horizontal grid spacing: 3 km
Vertical grids: 41 sigma layers
Assimilation: EnKF
Data: SST, T/S profiles, SLA

Period: 2001-2020
Open Boundary Data: daily HYCOM
Atmospheric forcing: ERA5 3hourly

3. Evaluation of Ocean Reanalysis Data in the East Sea

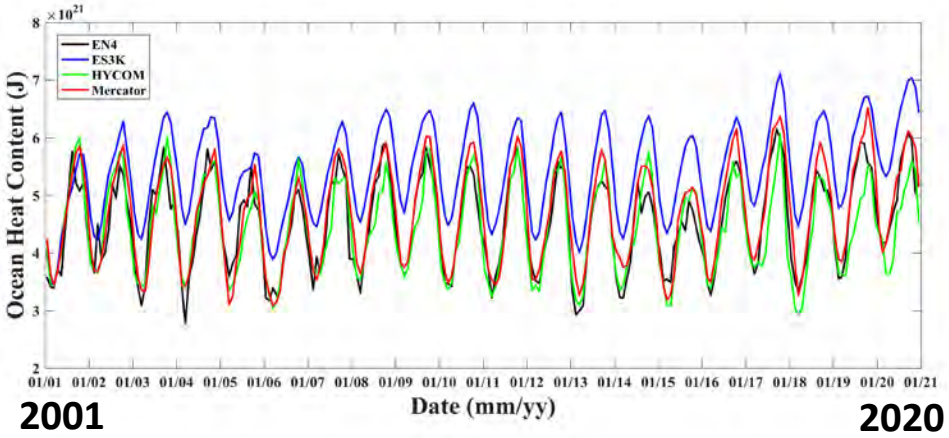
Ocean Heat Content (0–500dbar) – EN4, HYCOM, Mercator, ES3K



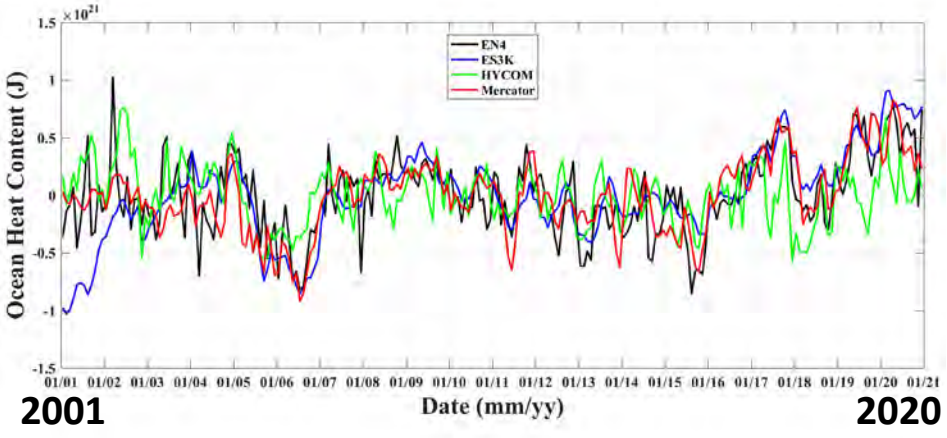
3. Evaluation of Ocean Reanalysis Data in the East Sea

Ocean Heat Content (0–500dbar) – EN4, HYCOM, Mercator, ES3K

Monthly OHC



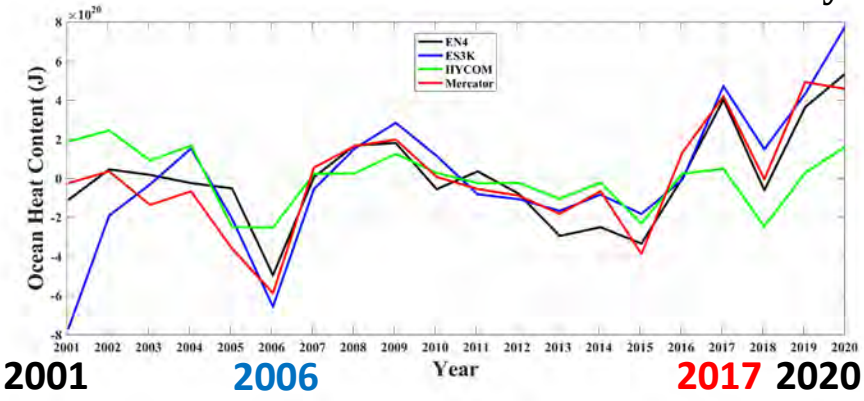
Non-seasonal variation of OHC



Monthly	ES3K	Mercator	HYCOM
R	0.91	0.94	0.89
Bias (J)	$9.06*10^{20}$	$1.74*10^{20}$	$-8.76*10^{19}$
RMSE (J)	$9.64*10^{20}$	$3.42*10^{20}$	$3.89*10^{20}$
cRMSE (J)	$3.01*10^{20}$	$2.63*10^{20}$	$3.50*10^{20}$

R: correlation coefficient
RMSE: root mean square error

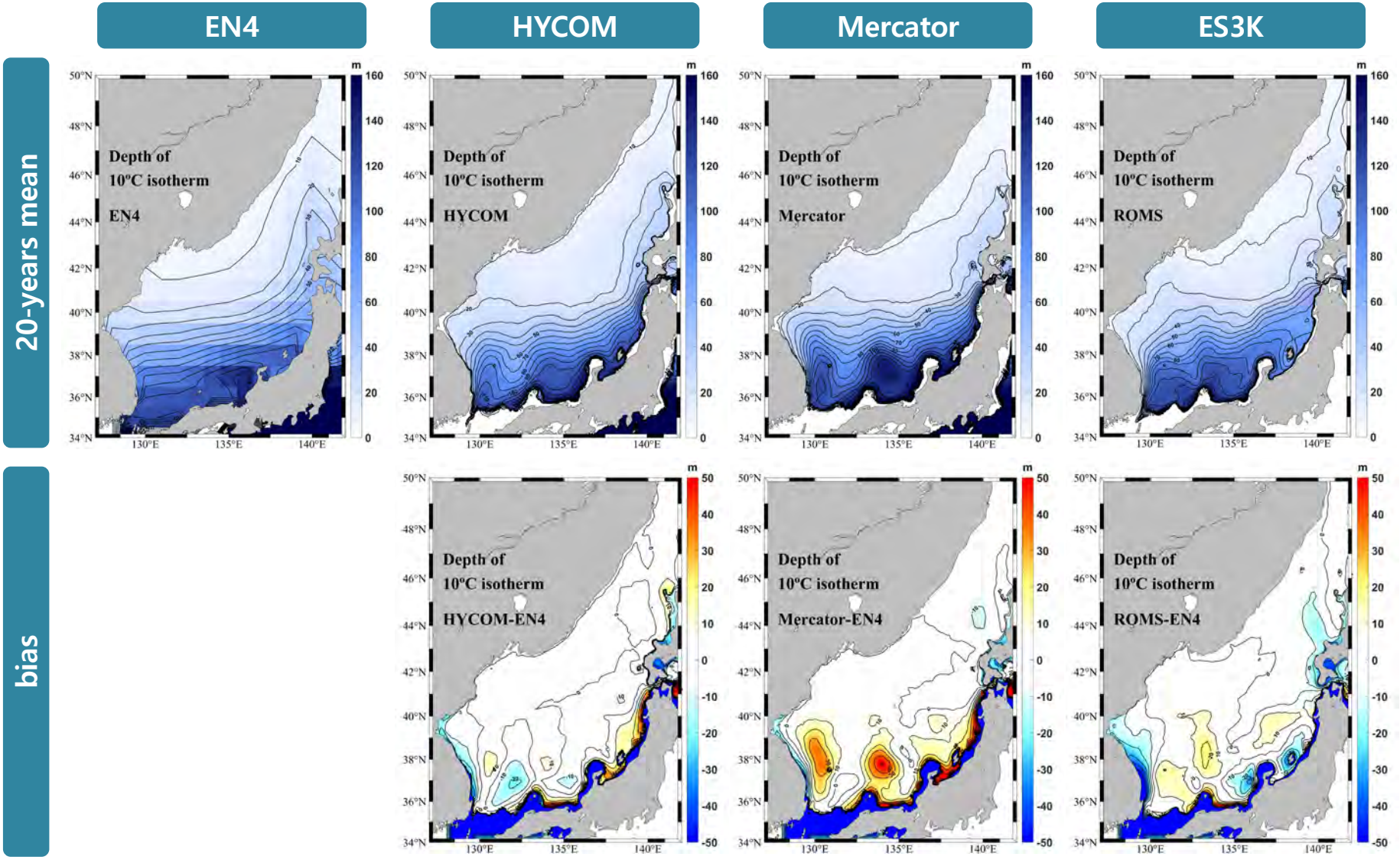
Variation of annual mean OHC anomaly



OHC was relatively lower in 2006, 2015, and 2018. It increased from 2016 to 2020 in EN4, Mercator, and ES3K.

3. Evaluation of Ocean Reanalysis Data in the East Sea

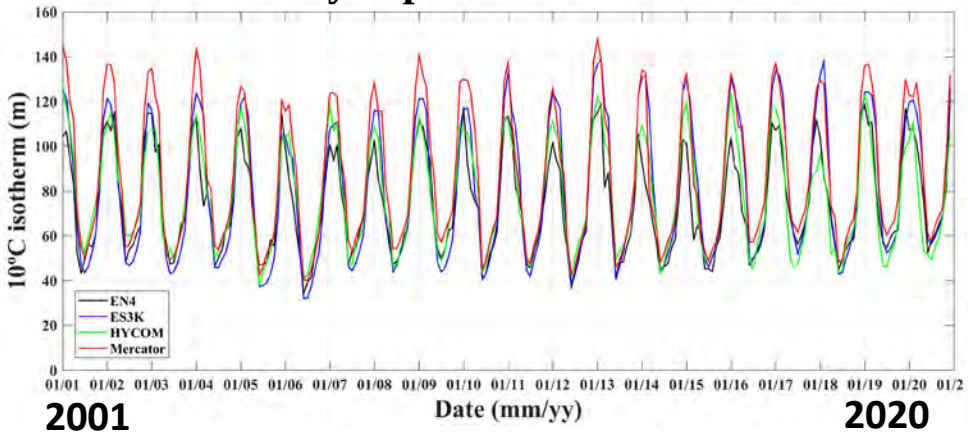
Depth of 10℃ isotherm – EN4, HYCOM, Mercator, ES3K Contour interval is 10 m.



3. Evaluation of Ocean Reanalysis Data in the East Sea

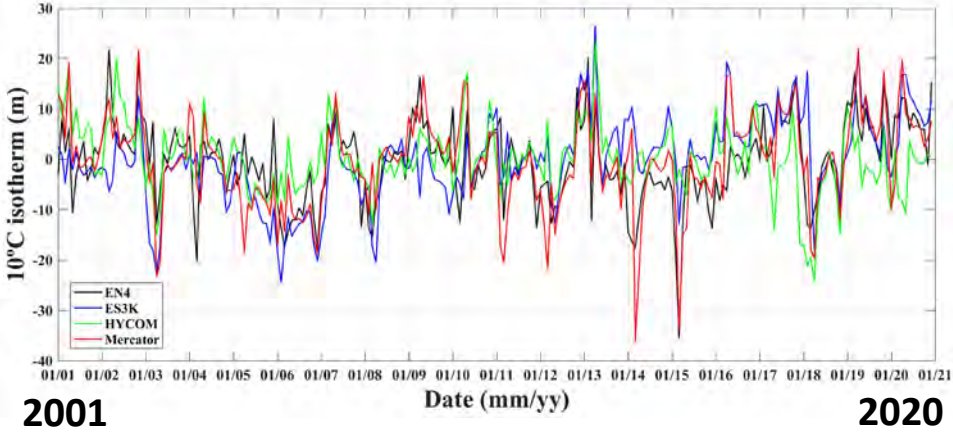
Depth of 10℃ isotherm – EN4, HYCOM, Mercator, ES3K

Monthly depth of 10℃ isotherm



2001 2020

Non-seasonal variation of 10℃ isotherm

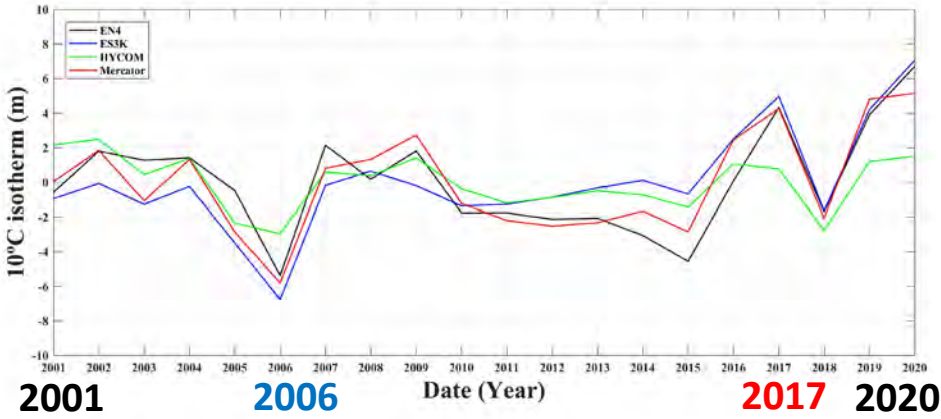


2001 2020

Monthly	ES3K	Mercator	HYCOM
R	0.93	0.96	0.92
Bias (m)	6.05	12.93	3.26
RMSE (m)	13.93	17.02	9.51
cRMSE (m)	8.37	6.87	8.41

R: correlation coefficient
RMSE: root mean square error

Annual mean depth of 10℃ isotherm anomaly



2001 2006 2017 2020

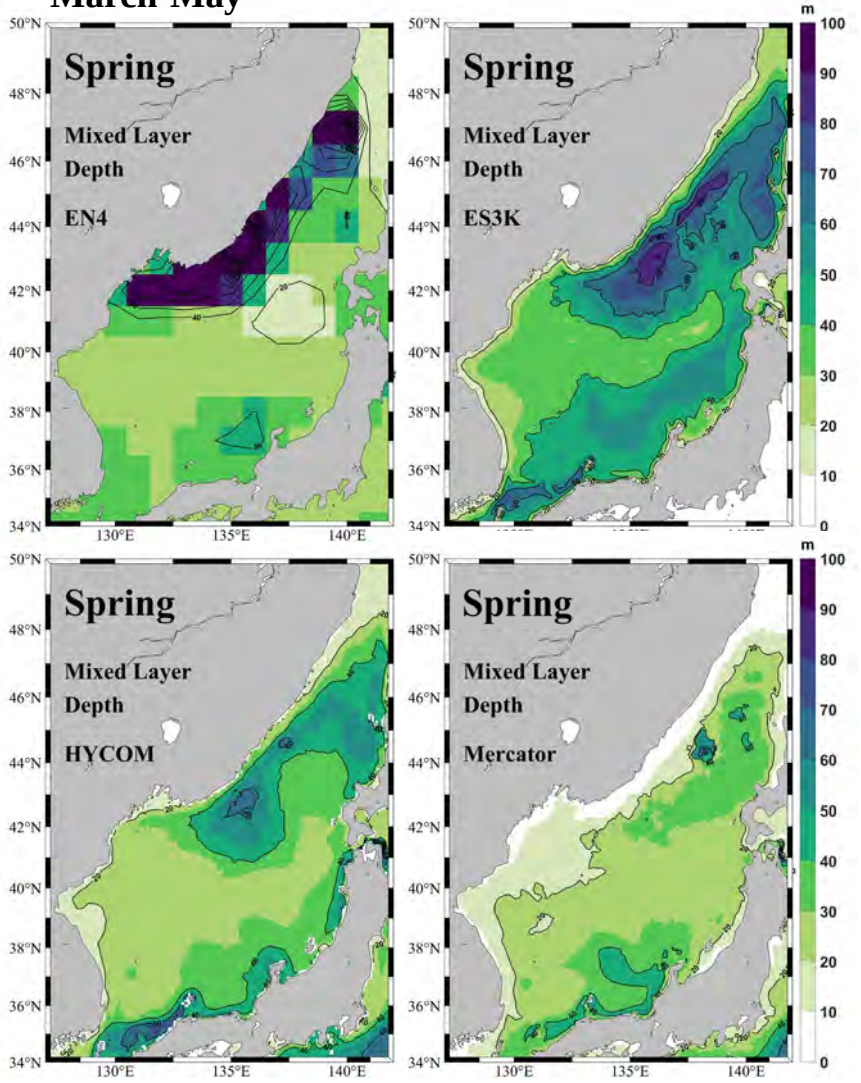
Depth of 10℃ isotherm was shallower in 2006, 2015, and 2018. It increased from 2016 to 2020 in EN4, Mercator, and ES3K.

3. Evaluation of Ocean Reanalysis Data in the East Sea

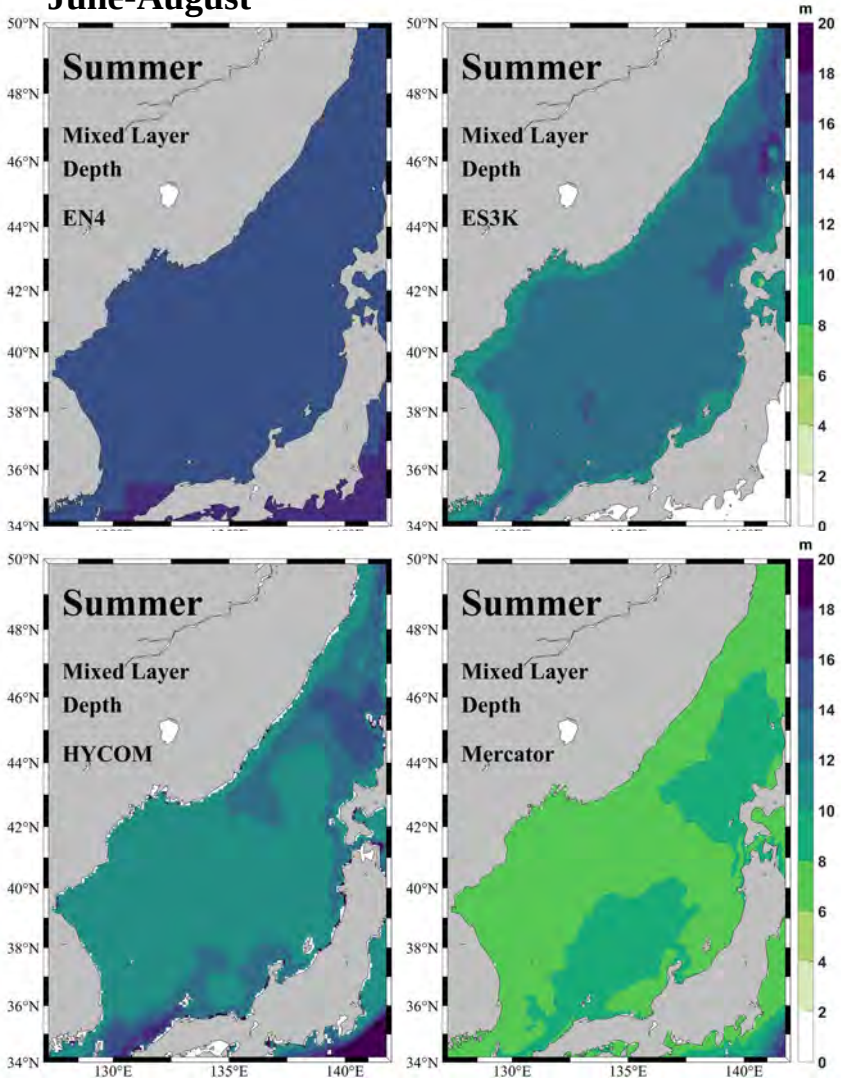
Mixed Layer Depth (m) – EN4, HYCOM, Mercator, ES3K (de Boyer Montégut et al., 2004)

Contour interval is 20 m.

March-May



June-August

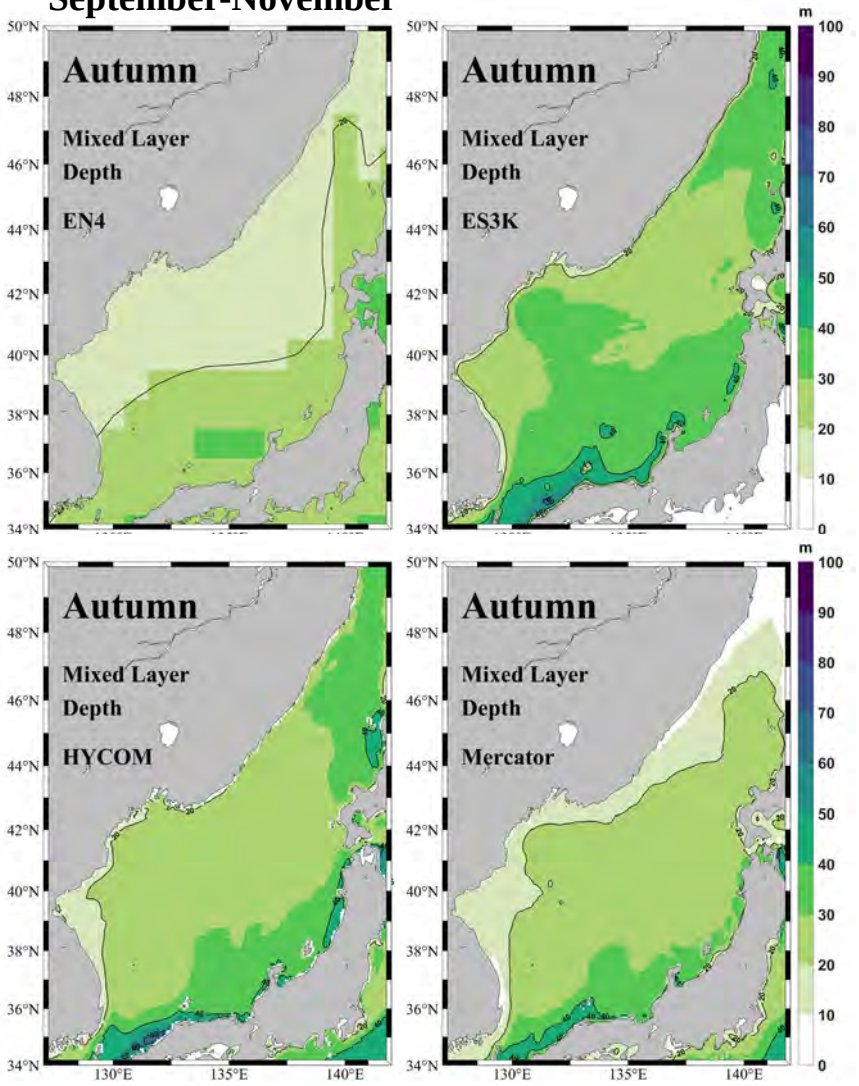


3. Evaluation of Ocean Reanalysis Data in the East Sea

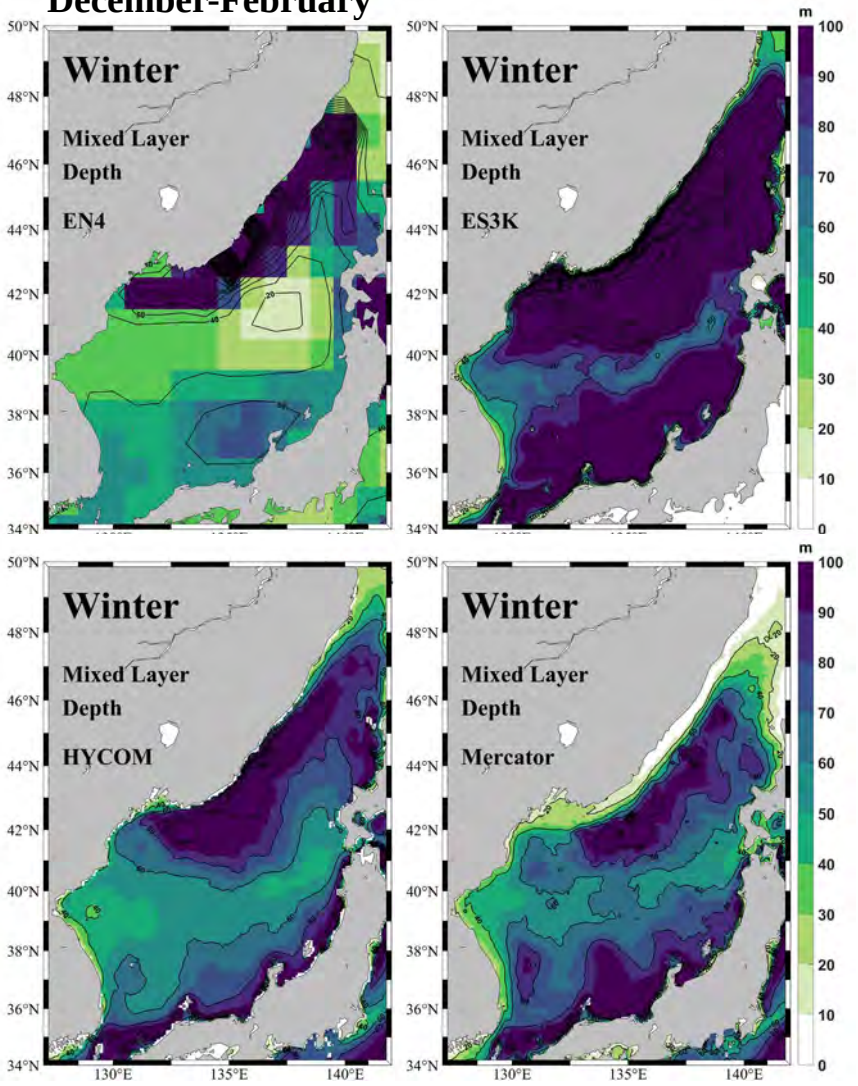
Mixed Layer Depth (m) – EN4, HYCOM, Mercator, ES3K (de Boyer Montégut et al., 2004)

Contour interval is 20 m.

September-November



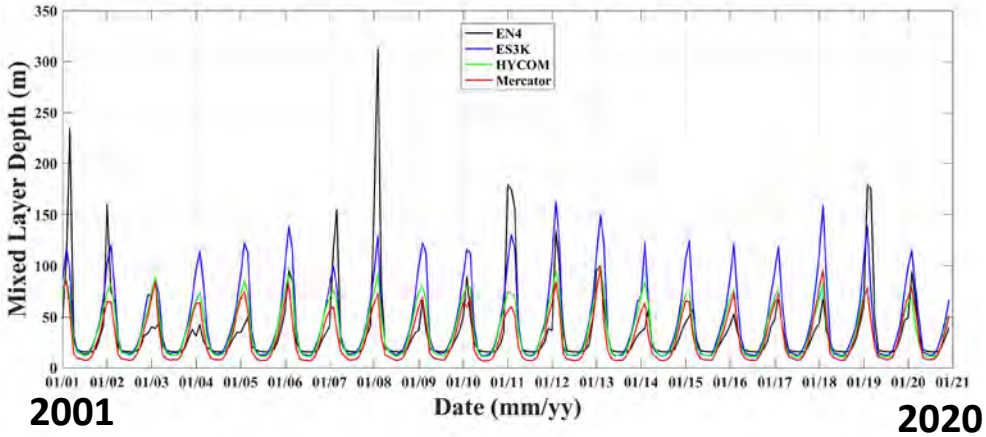
December-February



3. Evaluation of Ocean Reanalysis Data in the East Sea

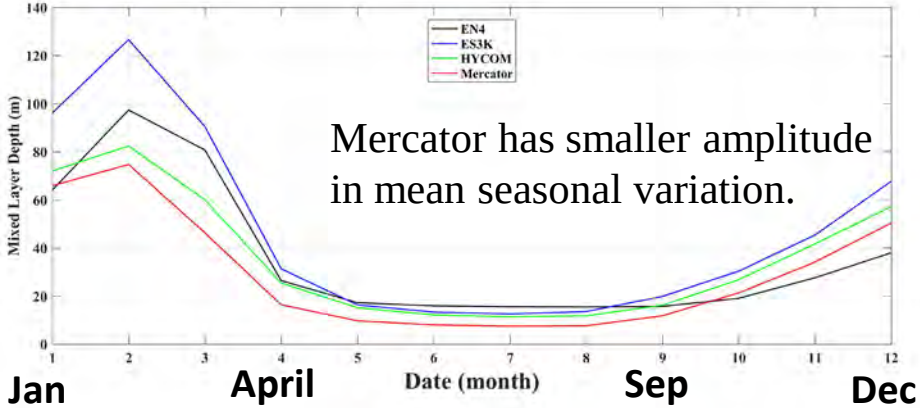
Mixed Layer Depth (m) – EN4, HYCOM, Mercator, ES3K

Monthly MLD



2001 2020

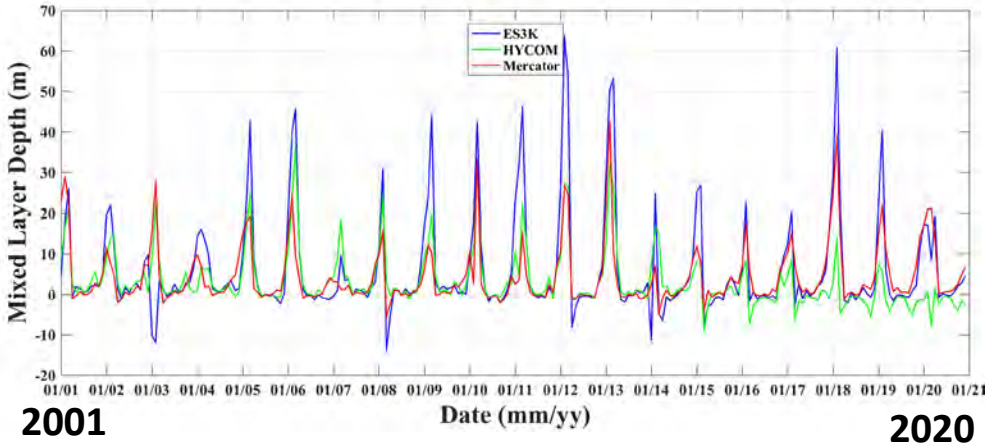
Mean Seasonal Variation of MLD



Mercator has smaller amplitude in mean seasonal variation.

Jan April Sep Dec

Monthly non-seasonal variation of MLD



2001 2020

Annual mean of MLD anomaly

2001 2007 2014 2020

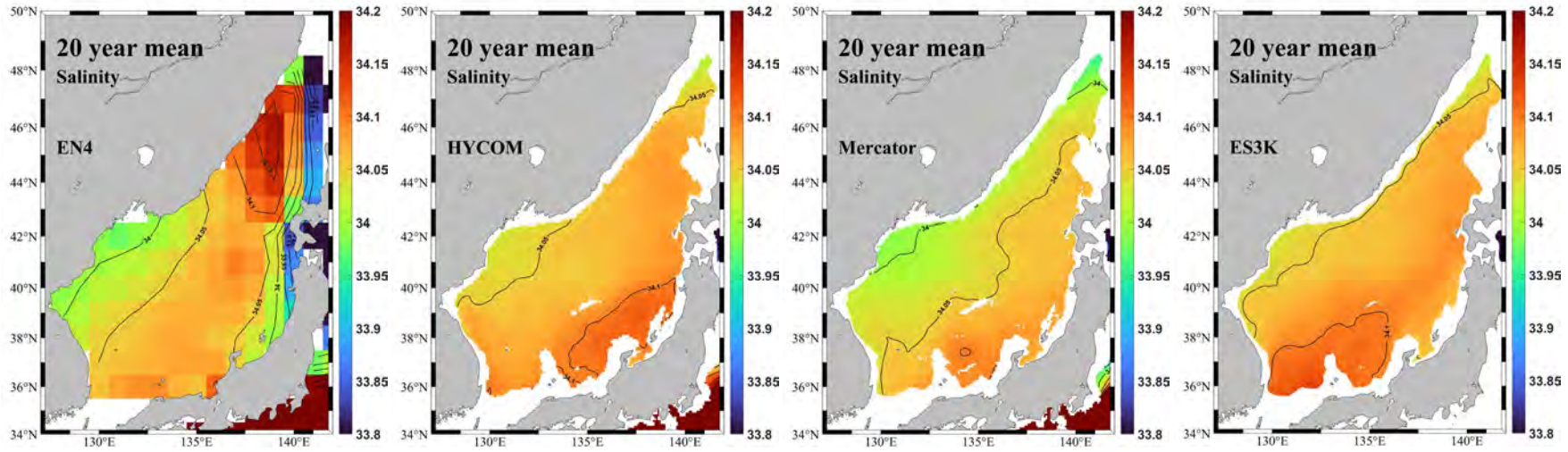
Mercator and ES3K has similar interannual variability in MLD.

3. Evaluation of Ocean Reanalysis Data in the East Sea

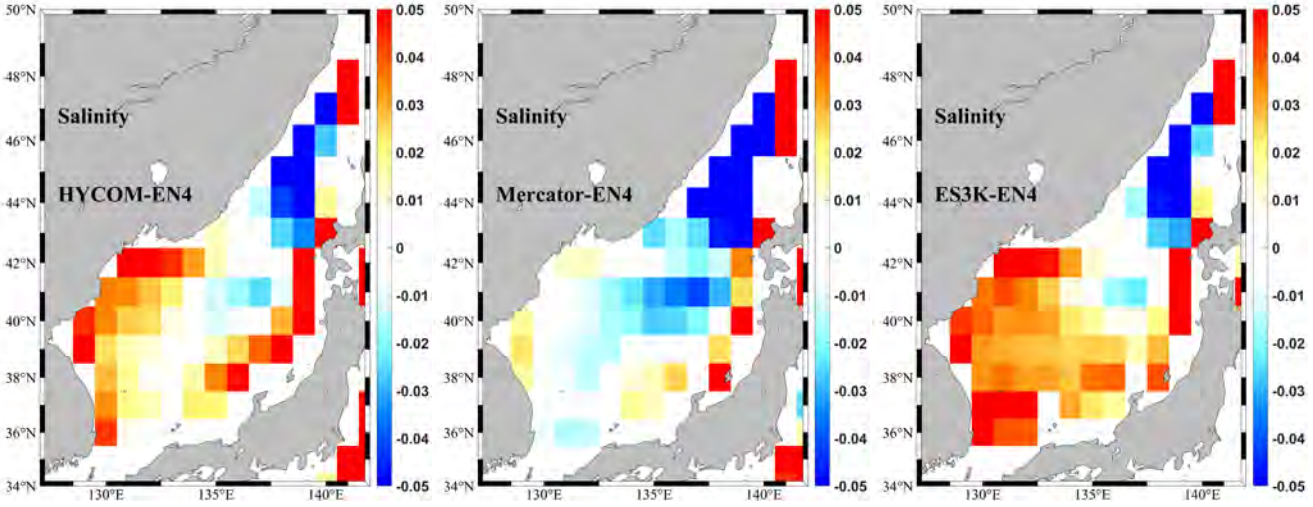
Salinity (0–500dbar) – EN4, HYCOM, Mercator, ES3K

EN4 | HYCOM | Mercator | ES3K

20-years mean



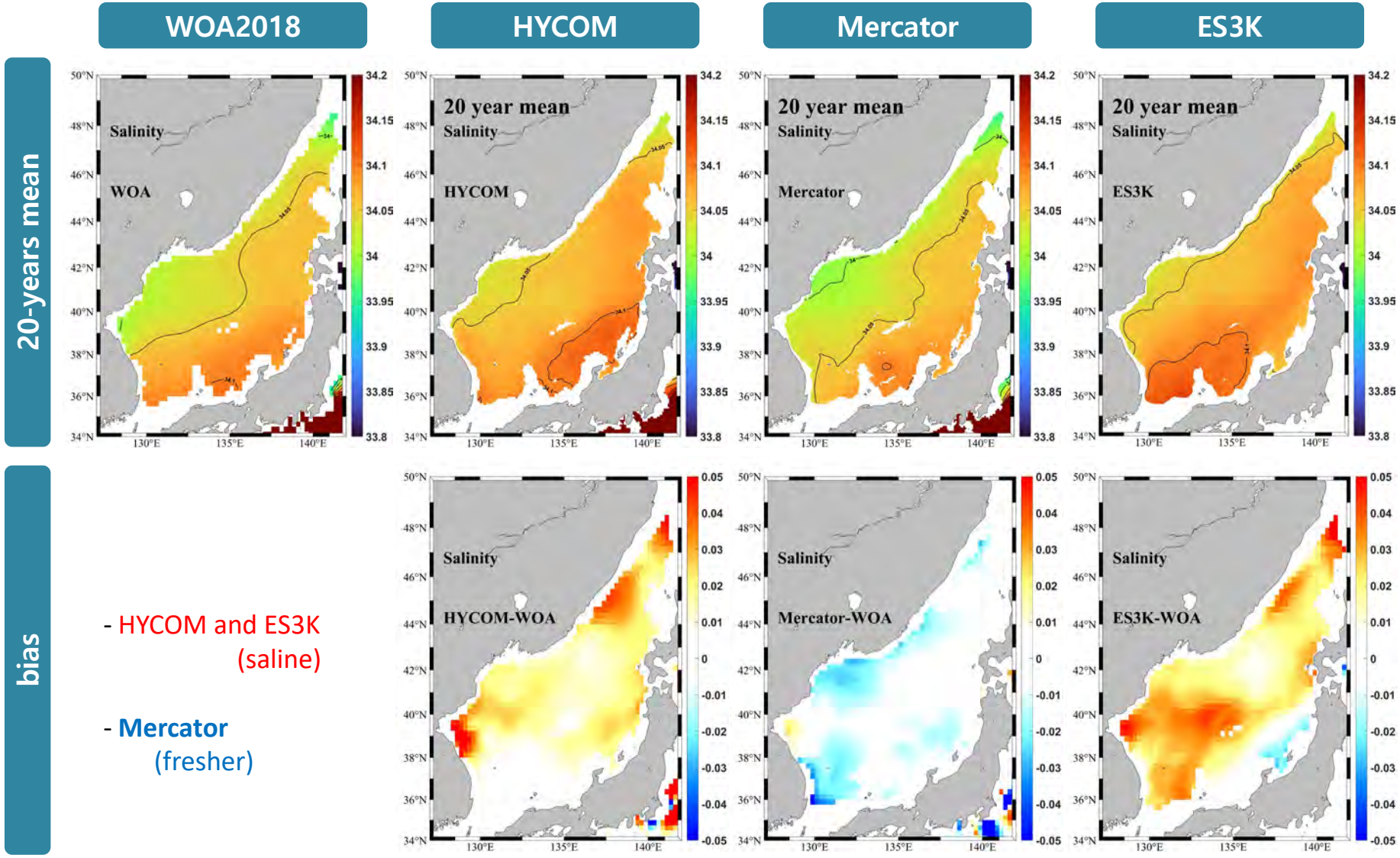
bias



- HYCOM and ES3K (saline)
- **Mercator** (fresher)

3. Evaluation of Ocean Reanalysis Data in the East Sea

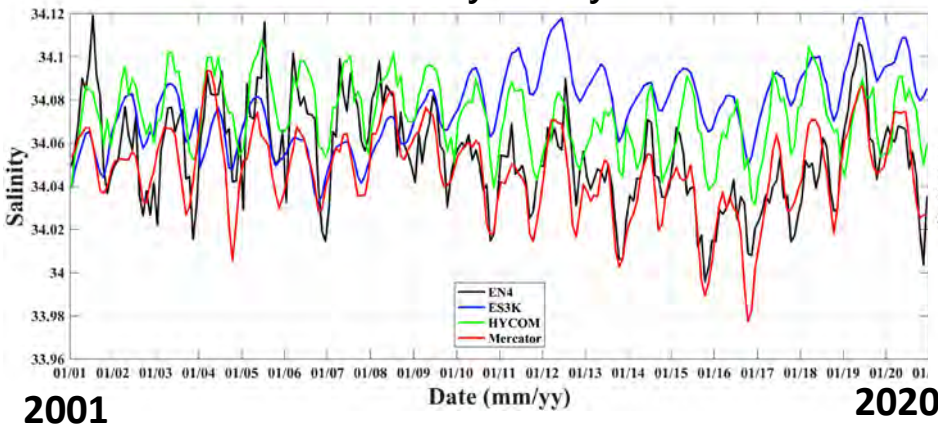
Salinity (0–500dbar) – EN4, HYCOM, Mercator, ES3K



3. Evaluation of Ocean Reanalysis Data in the East Sea

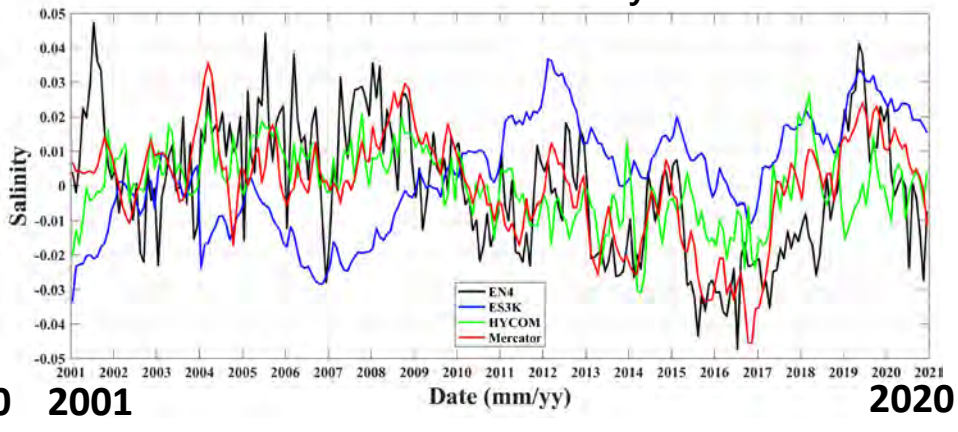
Salinity (0–500dbar) – EN4, HYCOM, Mercator, ES3K

Monthly Salinity



2001 2020

Non-seasonal Salinity

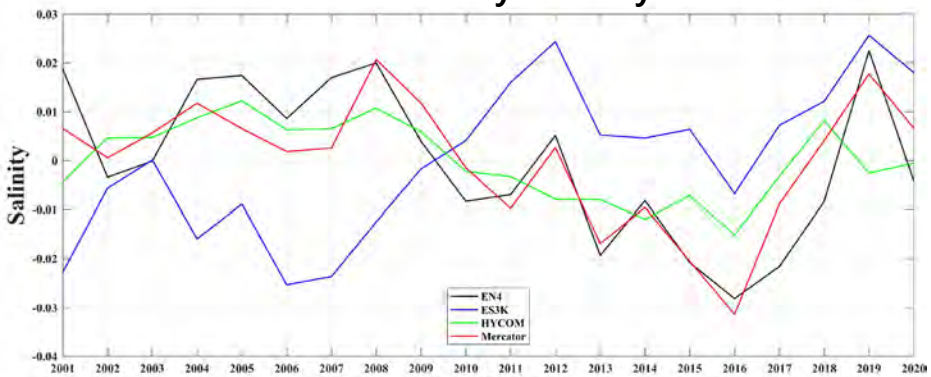


2001 2020

Monthly	ES3K	Mercator	HYCOM
R	0.07	0.74	0.63
Bias	0.02	-0.01	0.02
RMSE	0.03	0.02	0.03
cRMSE	0.03	0.01	0.02

R: correlation coefficient
RMSE: root mean square error

Annual Salinity anomaly

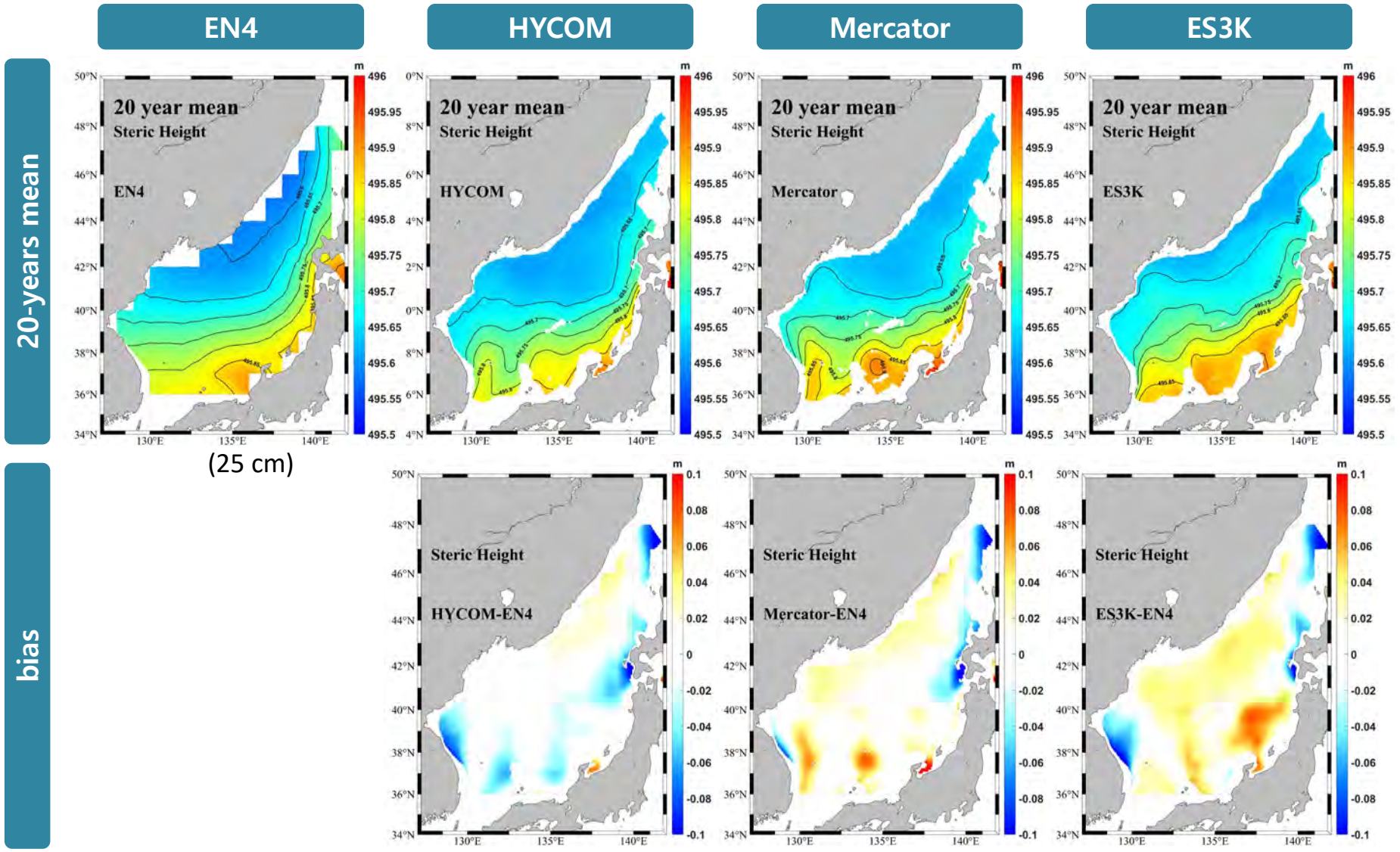


2001 2008 2016 2020

Salinity decreased from 2008 to 2016 in EN4, HYCOM, and Mercator. It recovered from 2017 to 2019.

3. Evaluation of Ocean Reanalysis Data in the East Sea

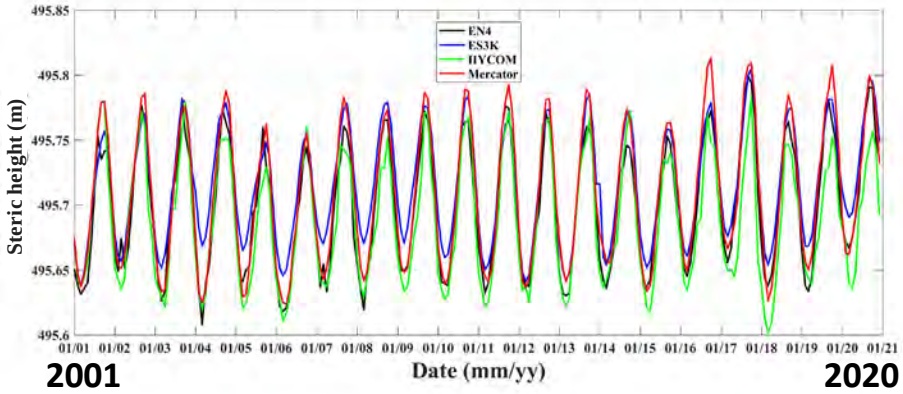
Steric Height (0–500dbar) – EN4, HYCOM, Mercator, ES3K Contour interval is 5 cm.



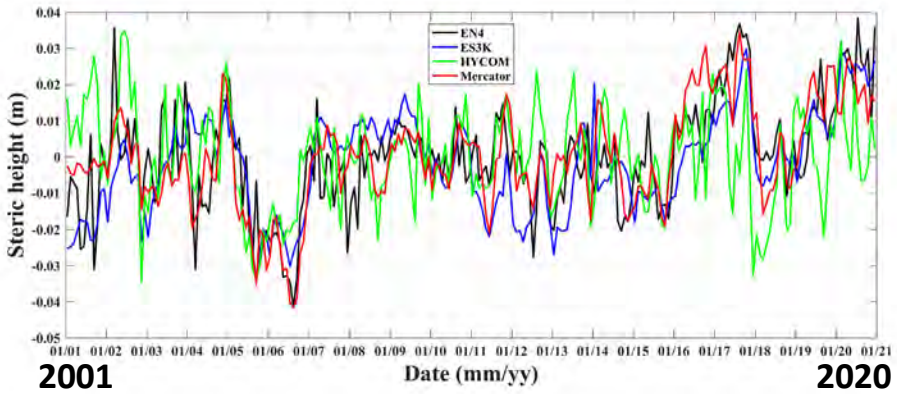
3. Evaluation of Ocean Reanalysis Data in the East Sea

Steric Height (0–500dbar) – EN4, HYCOM, Mercator, ES3K

Monthly variation of Steric Height (m)



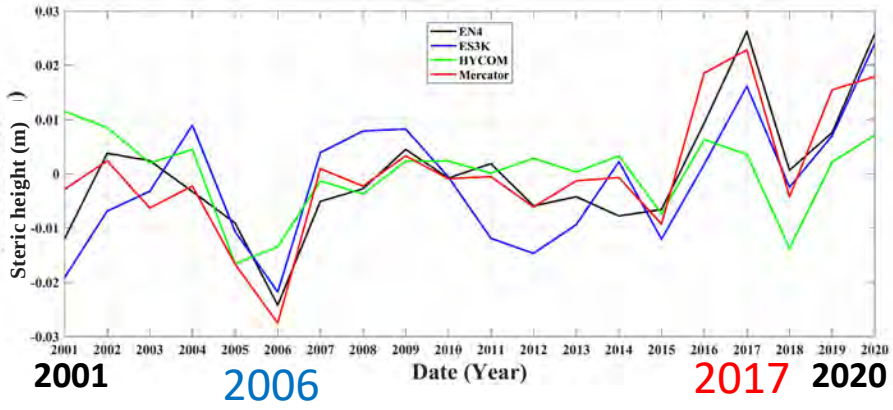
Monthly non-seasonal variation of Steric Height



Monthly	ES3K	Mercator	HYCOM
R	0.96	0.97	0.93
Bias (m)	0.02	0.01	-0.01
RMSE (m)	0.02	0.02	0.02
cRMSE (m)	0.01	0.02	0.01

R: correlation coefficient
RMSE: root mean square error

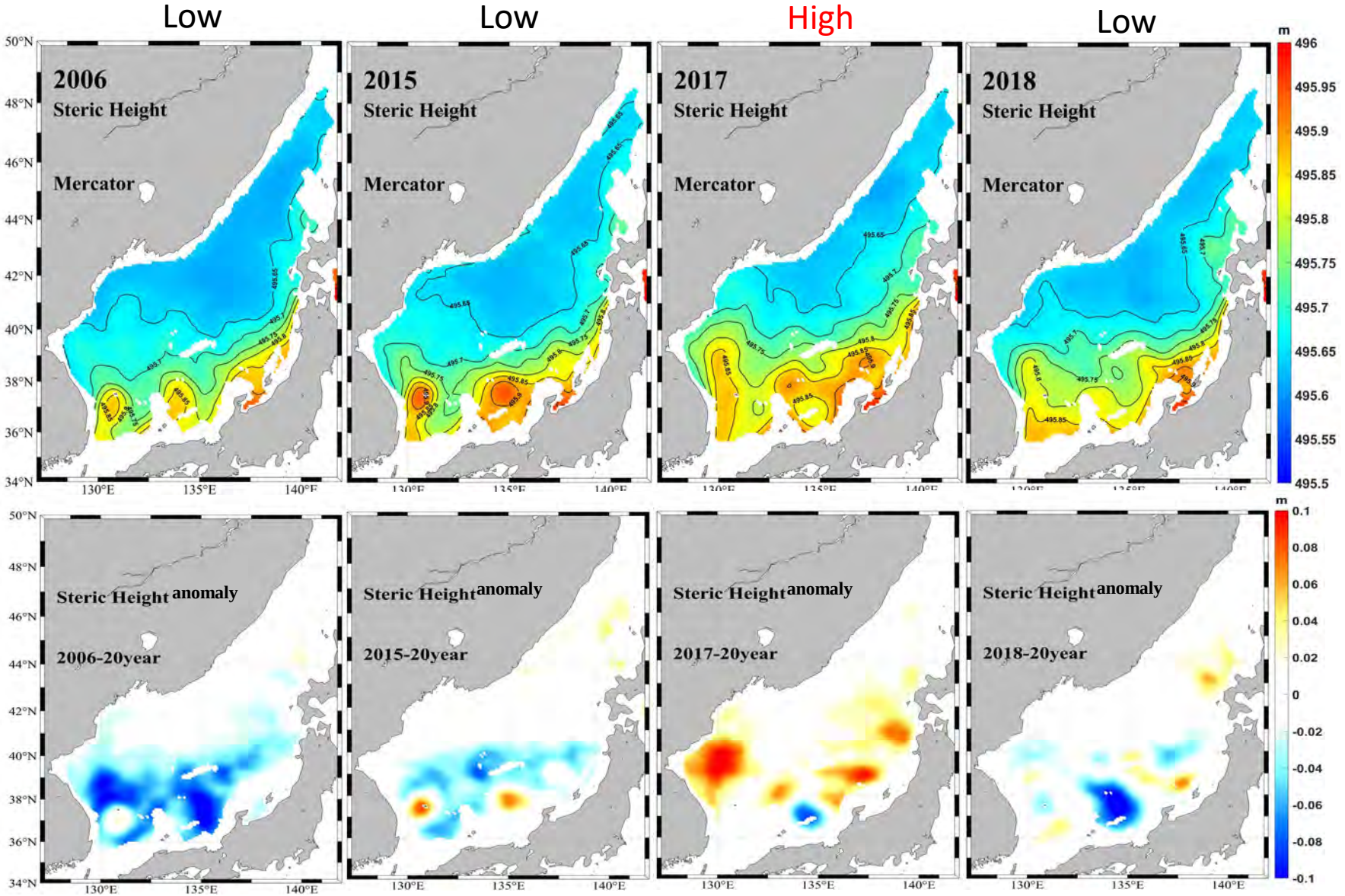
Annual mean of Steric Height anomaly



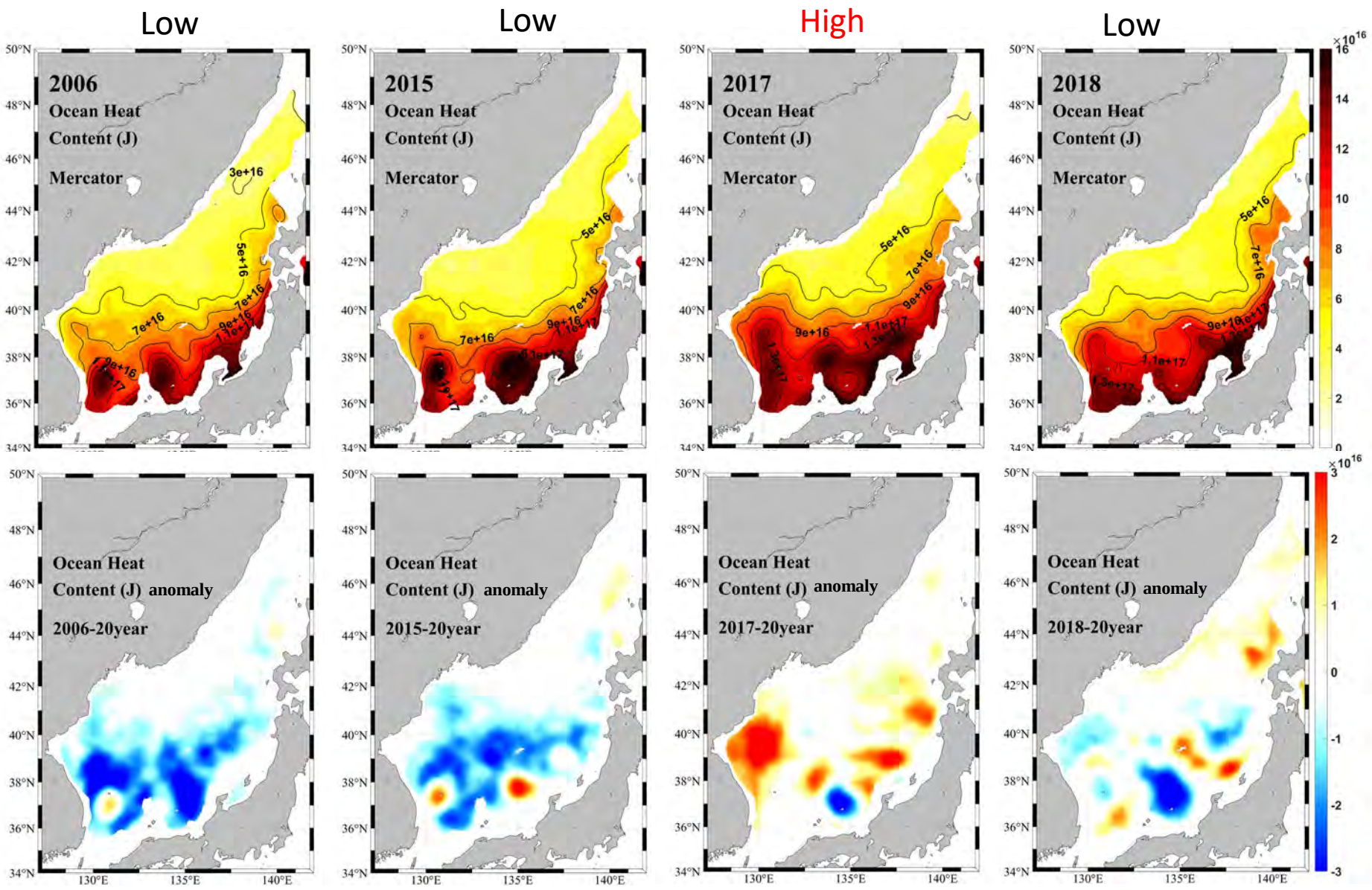
Steric height was lower in 2006 and 2018 while it was higher in 2017 and 2020.
It increased from 2016 to 2020 in EN4, Mercator, and ES3K.

Steric Height (0-500dbar)

Contour interval is 5 cm.

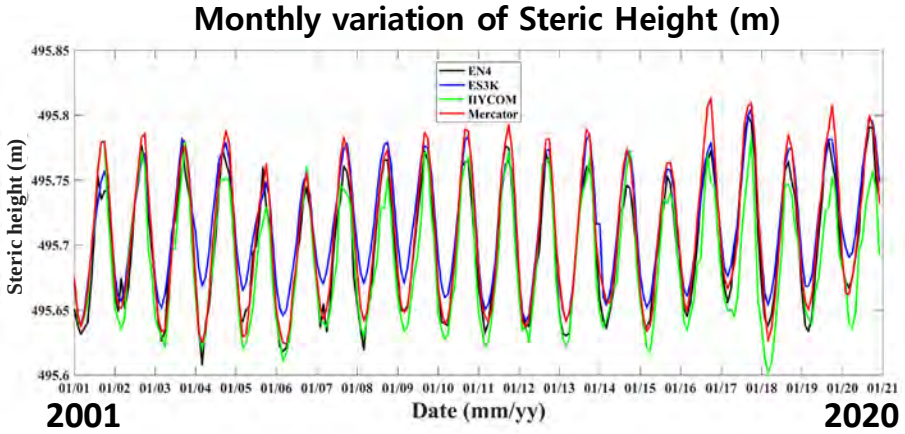


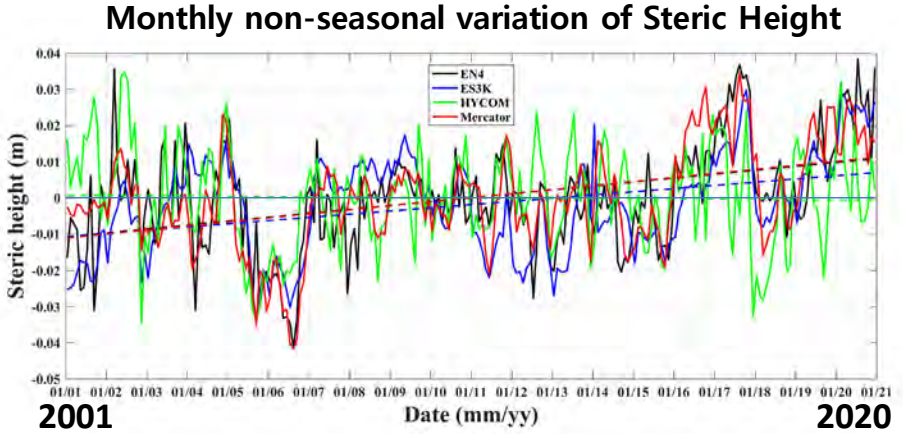
Ocean Heat Content (0-500dbar)



3. Evaluation of Ocean Reanalysis Data in the East Sea

Steric Height (0–500dbar) – EN4, HYCOM, Mercator, ES3K





Monthly	ES3K	Mercator	HYCOM
R	0.96	0.97	0.93
Bias (m)	0.02	0.01	-0.01
RMSE (m)	0.02	0.02	0.02
cRMSE (m)	0.01	0.02	0.01

R: correlation coefficient
RMSE: root mean square error

Steric height was lower in 2006 and 2018.
It increased from 2016 to 2020 in EN4, Mercator, and ES3K.

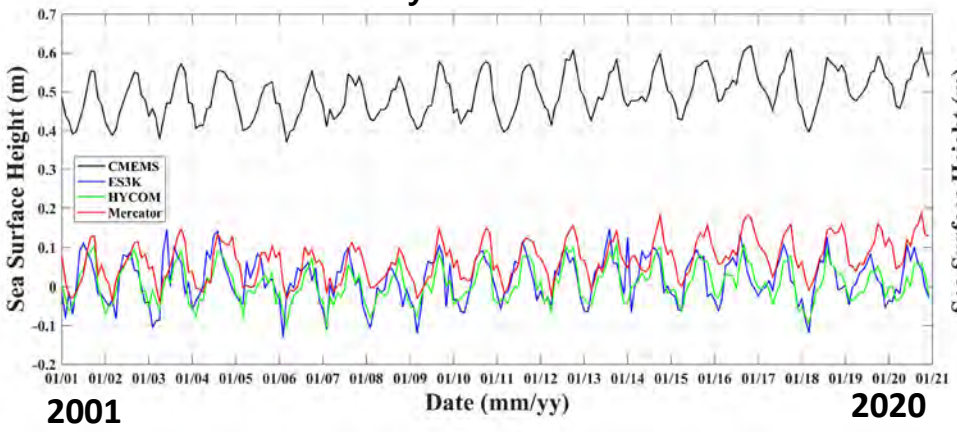
	EN4	HYCOM	Mercator	ES3K
Linear Trend (**cm/yr**)	**0.11**	-0.01	**0.11**	**0.09**

Steric height increased approximately 2 cm for 20 years

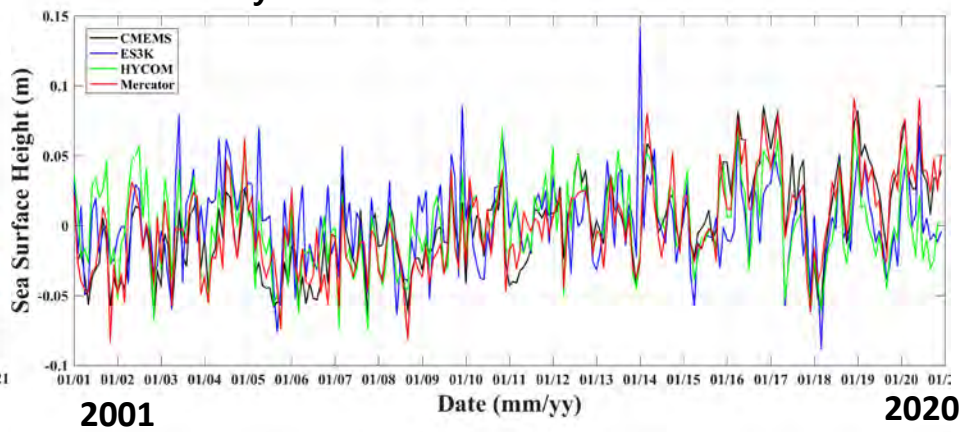
3. Evaluation of Ocean Reanalysis Data in the East Sea

Sea level – CMEMS, HYCOM, Mercator, ES3K

Monthly mean sea level



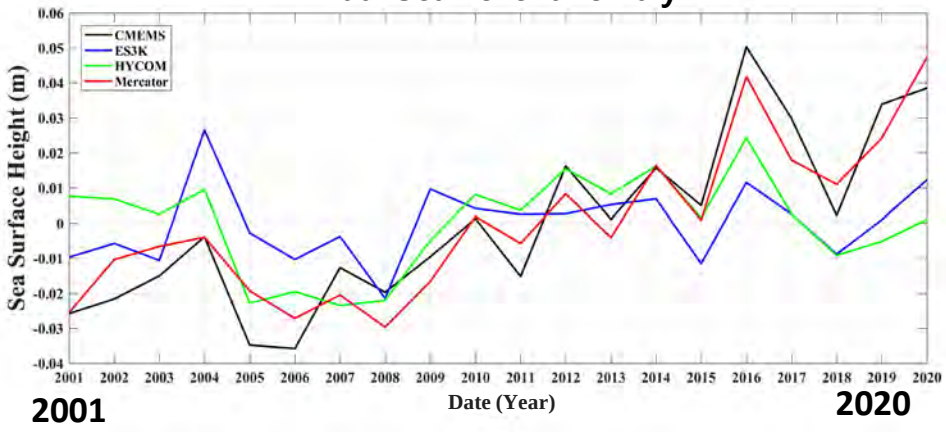
Monthly nonseasonal variation of sea level



Monthly	ES3K	Mercator	HYCOM
R	0.53	0.96	0.83
cRMSE (m)	0.03	0.02	0.03

R: correlation coefficient
RMSE: root mean square error

Annual Sea Level anomaly



Sea level increased from 2008 to 2016 in all reanalysis datasets. It increased from 2016 to 2020 in **satellite altimeter observation** and Mercator while it decreased in HYCOM and ES3K.

4. Summary

Ocean reanalysis data from HYCOM, Mercator, and ES3K were compared with **observation data** such as EN4 and WOA2018.

OHC: ES3K has warm bias. HYCOM has smaller interannual variability.

Depth of 10℃ isotherm: Mercator has relatively deeper depths of 10℃ isotherm. HYCOM has smaller interannual variability. Depth of 10℃ isotherm was shallower in 2006, 2015, and 2018 while it was deeper 2017 and 2020.

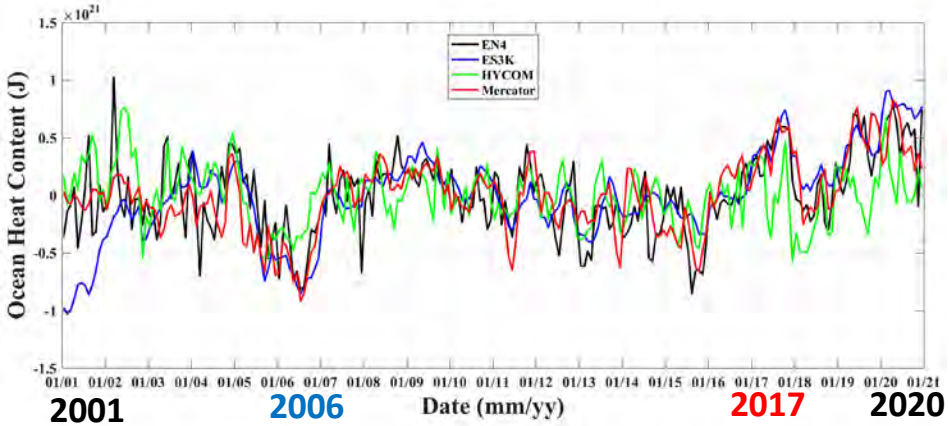
MLD: Mercator has smaller range in mean seasonal variation.
MLD is thicker than other analysis in winter.
Time series of analysis data diverge each other.
Mercator and ES3K has similar interannual variability in MLD.

Salinity: **HYCOM** and **ES3K** have saline bias while **Mercator has** fresh bias. Salinity decreased from 2008 to 2016 in EN4, HYCOM, and Mercator and then recovered from 2017 to 2019. Time series of analysis data from **ES3K** diverge from the others.

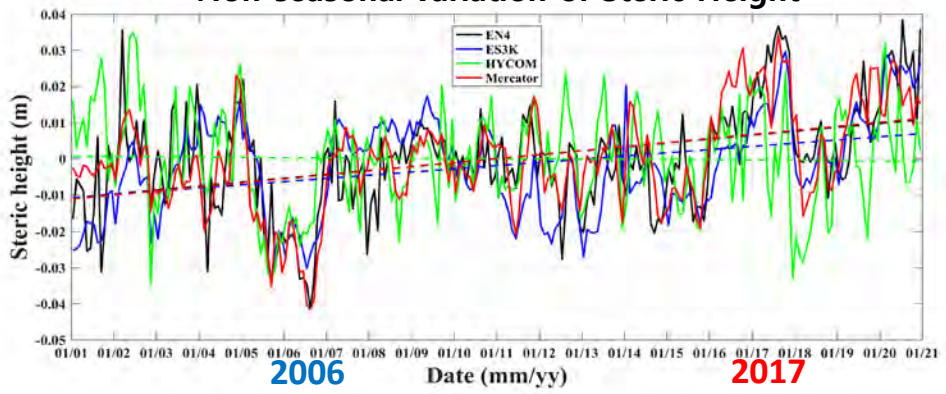
Steric height: Steric height was lower in 2006 and 2018 while it was higher in 2017 and 2020. It increased from 2016 to 2020 in **EN4**, Mercator, and ES3K.
Steric height increased approximately 2 cm for 20 years

Sea level: **Satellite altimeter** observation and Mercator have a increasing trend.

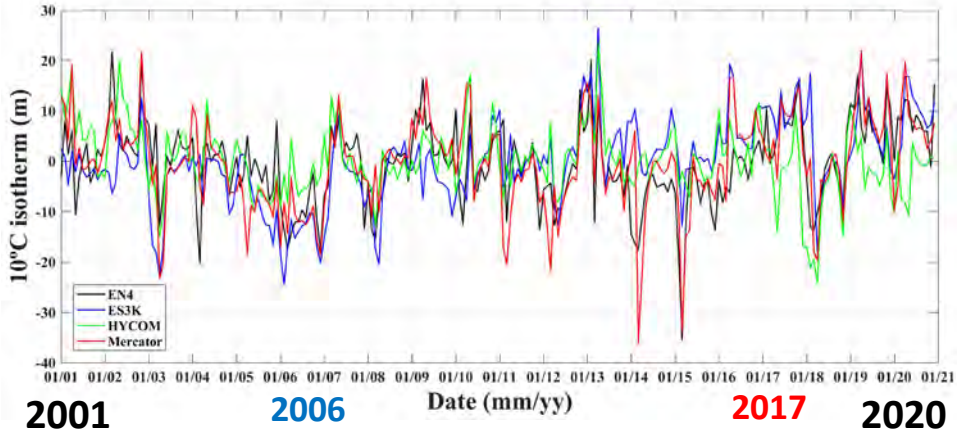
Non-seasonal variation of Ocean Heat Content



Non-seasonal variation of Steric Height

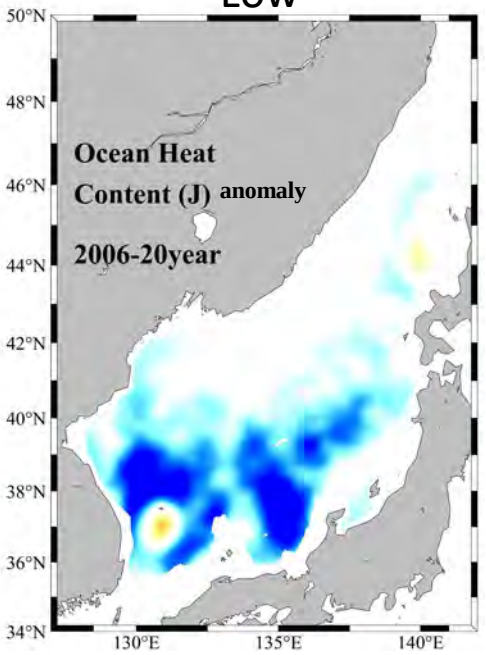


Non-seasonal variation of 10°C isotherm

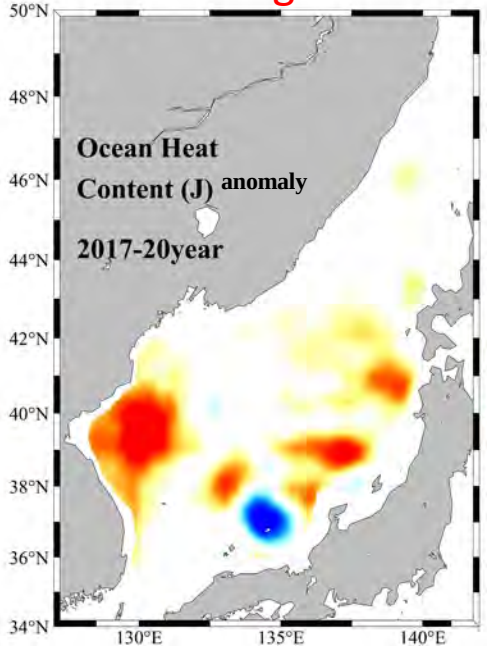


EN4,
HYCOM
Mercator
ES3K

Low



High



Thank you for your attention!