Ocean Predict

SYMPOSIUM OP'24

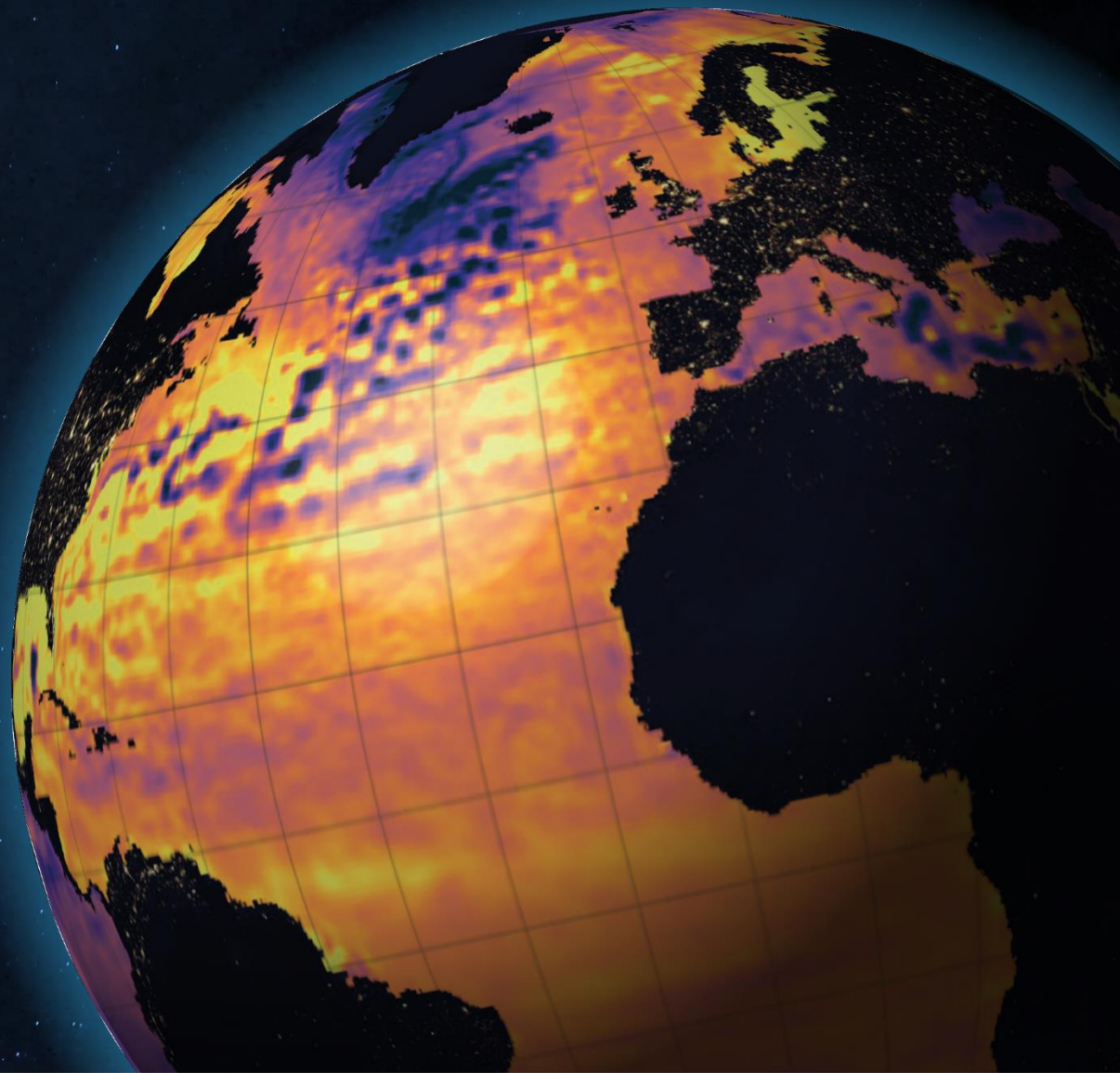
In partnership with unesco Intergovernmental Oceanographic Commission

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Numerical simulation of the Northwest Pacific based on "Matsu"-family Ocean Models

- Zhaoyi WANG, Liying WAN, Boyu FENG & Yu ZHANG

- 2024.11.20, Paris



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NMEFC: “Matsu”-family Ocean Models

Matsu (妈祖), Chinese sea goddness

- **Matsu-family models including:**
  - **MaCOM**, Mass Conservation Ocean-seaice Model)
  - MaCOM-SI, sea ice components
  - **FVWAM**, Finite Volume WAve Model

  - Storm Surge Flooding Model
  - Realtime GPU-based Tsunami Model （CTSU v3.0)

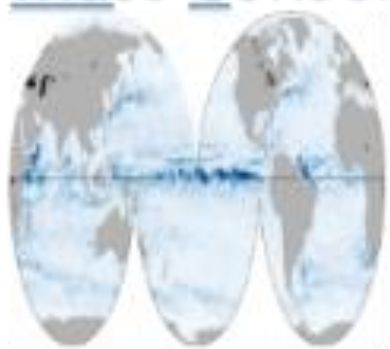
- **Aims to be**

  Self-sustained, Light-weighted

MaCOM introduction

NAME	MaCOM
Copyright	NMEFC
Main features	pressure/height coordinates, conservation of mass/volume, static equilibrium, separation of normal and oblique pressure, global (spherical cube grid)/regional (latitude and longitude grid), tides, unstructured parallel computing, independent asynchronous IO, GPU supported computing
Existing issues	● No single core CPU and requires at least 6 cores (4 cores for computing and 2 cores for IO); ● No sea ice, ecology, coupler interface ● No rotation along the equidensity plane mixing

Mass Conservation Ocean Model



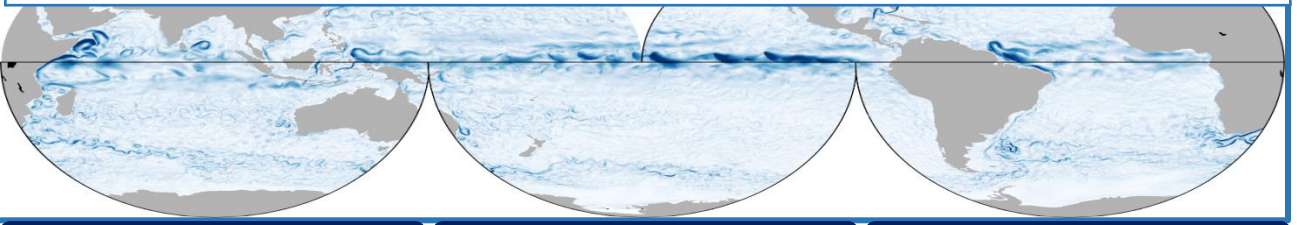
aCOM

https://macom.oceanguide.org.cn/

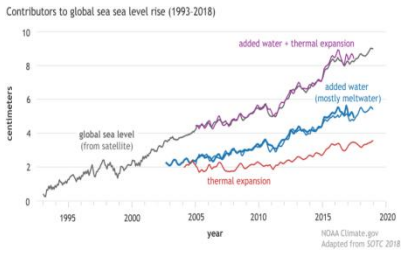
MaCOM Application: Global

MaCOM advantage

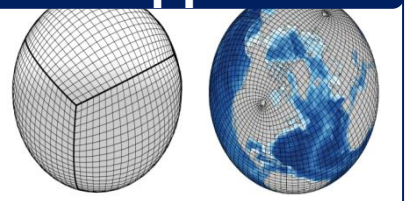
Self-developed, operational-forecast-using and medium-short-term circulation forecasting needs

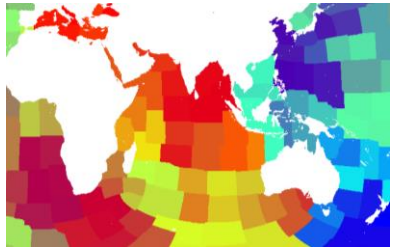


1 mass conservation

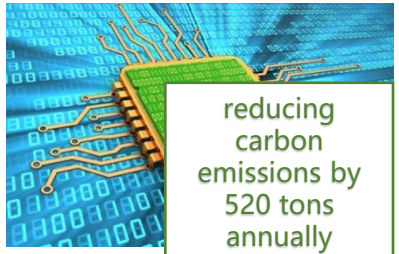


2 Grid support



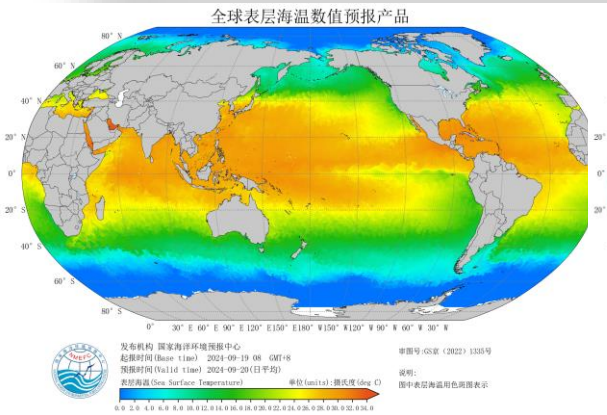


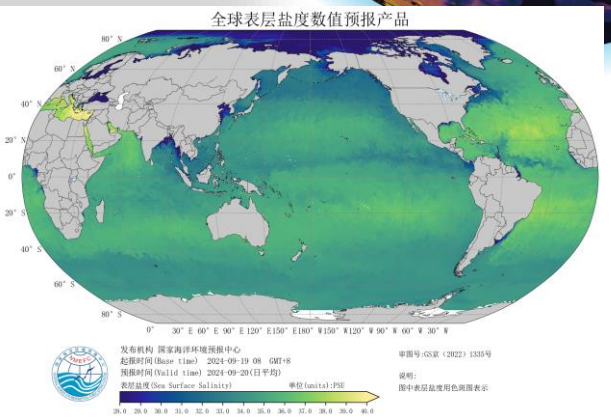
3 GPU Parallel

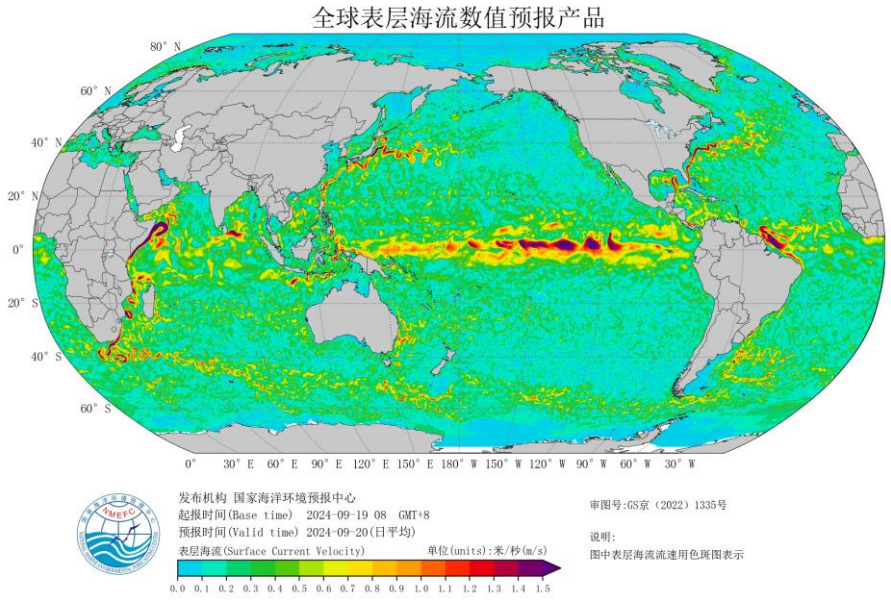


reducing carbon emissions by 520 tons annually

Products





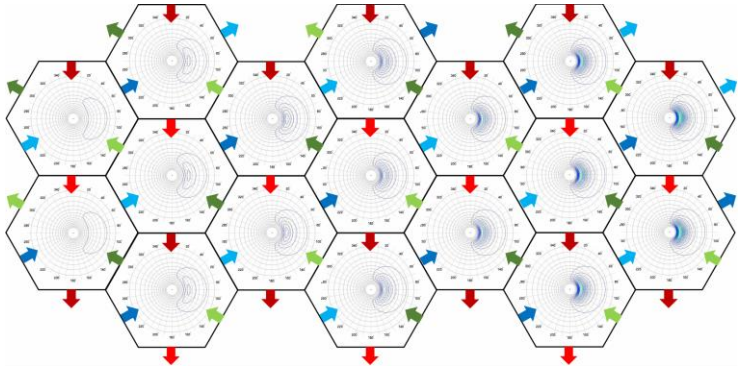


Finite-Volume WAve Model (FVWAM)

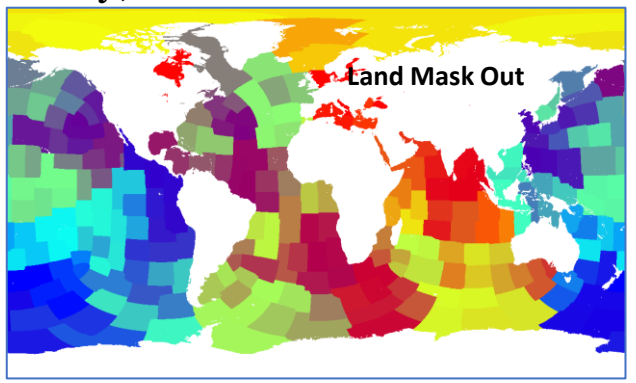
a GPU-accelerated, WAM-family ocean wave model based on unstructured Voronoi meshes

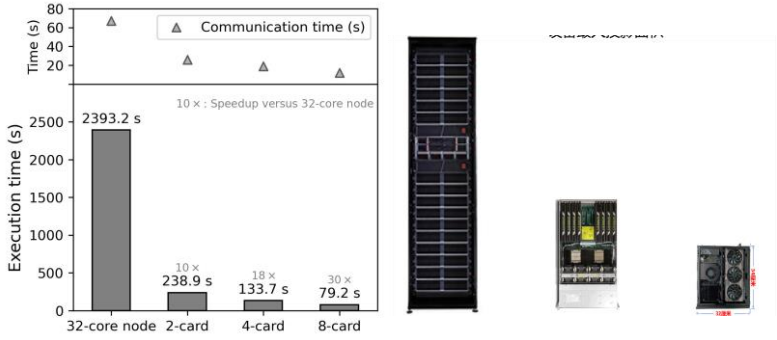
FVWAM is a WAM-family model with the following features:

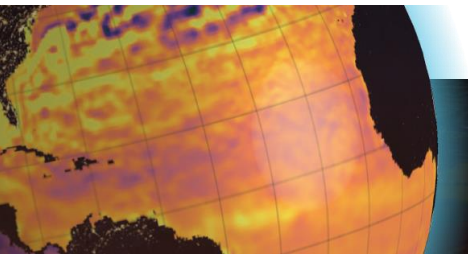
- WAM-family: source terms entirely from WAM6 (Mywave project)
- Finite Volume Approach based on the unstructured Voronoi meshes is ported to the WAM6 for wave propagation.
  - Seamless integration of global to regional modeling
- Efficient domain decomposition for scalability, and GPU acceleration empowered by OpenACC.
  - Lightweighted and “Green”



Propagation scheme based on FVM

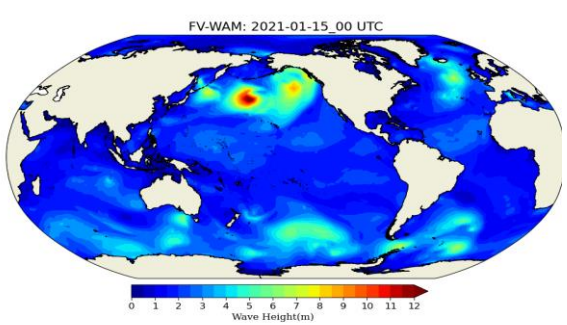


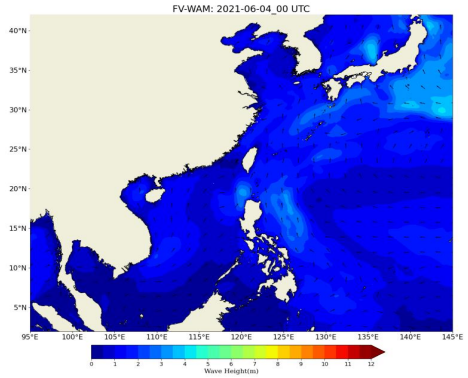


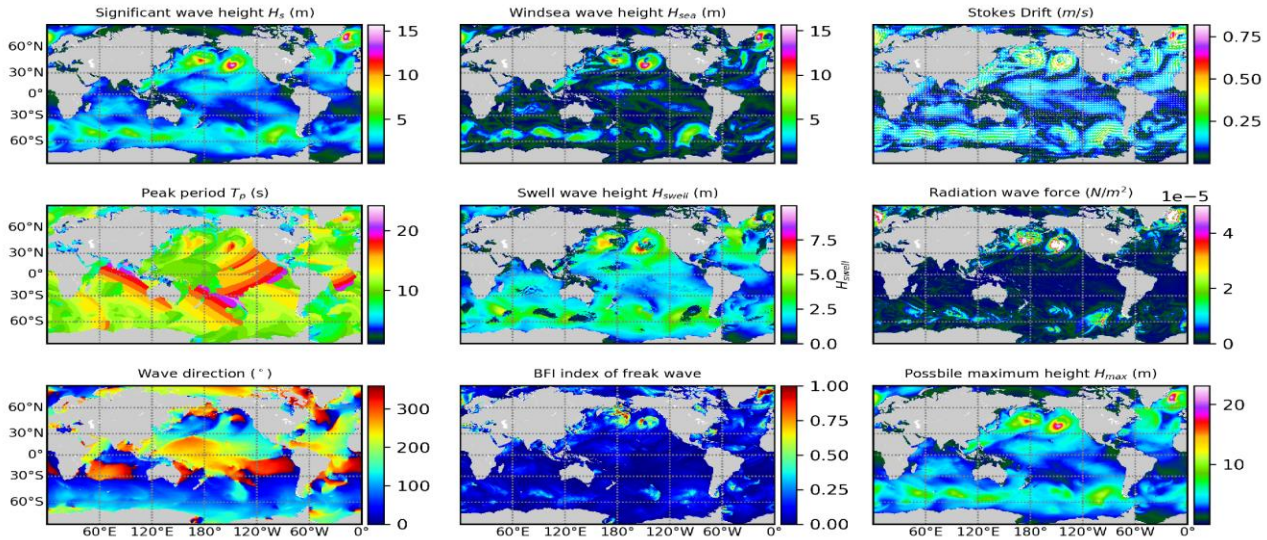


FVWAM Application: Routine Forecasts

Daily operation, Twice	
Wind force	GRAPES/CMA, GFS/NCEP, or Holland parametric wind model
Spatial resolution	Global10km -> NWP 6km
Spectral resolution	36 Directions &35 Frequencies 0.0375 ~ 1.0Hz
Time step	120 s
Forecast valid	7 d
Updated at	00UTC， 12UTC
Output	SWH, Tp, Direction
Output interval	1hrs







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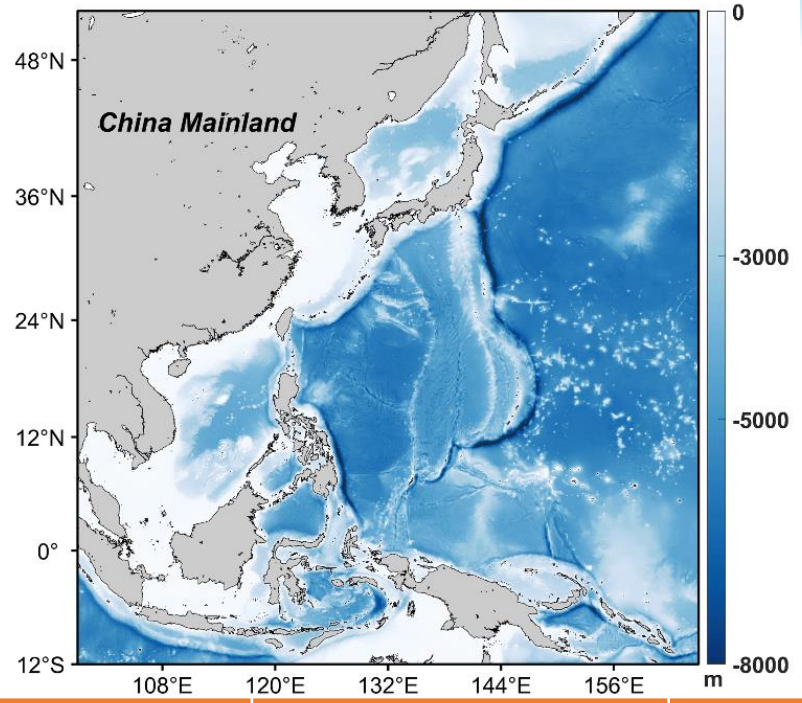
System configuration

Name	factors
longitude	98°~165°
latitude	-12°~52°
horizontal resolution	1/24°
Vertical resolution	75 z-levels
Topo	earth_Relief_01m
Coastal data	GSHHG_v2.3.7_1m
Open boundary	GLORY 1/12°
Atmospheric forcing	JRA55-DO
Tidal forcing	TPXO9



	Volume Conservation	Mass Conservation
Hardware	CPU (Intel Xeon*20)	GPU (A100*6)
Compute Time	7~9min/d	5~7min/d
Hindcast	28 model years (1993-2020) without tidal	
DA Expr.	3DVar with / without tidal	

MaCOM_V: MaCOM Volume Conservation Version
MaCOM_P: MaCOM Mass Conservation Version

Hindcast validation: SST&SSS

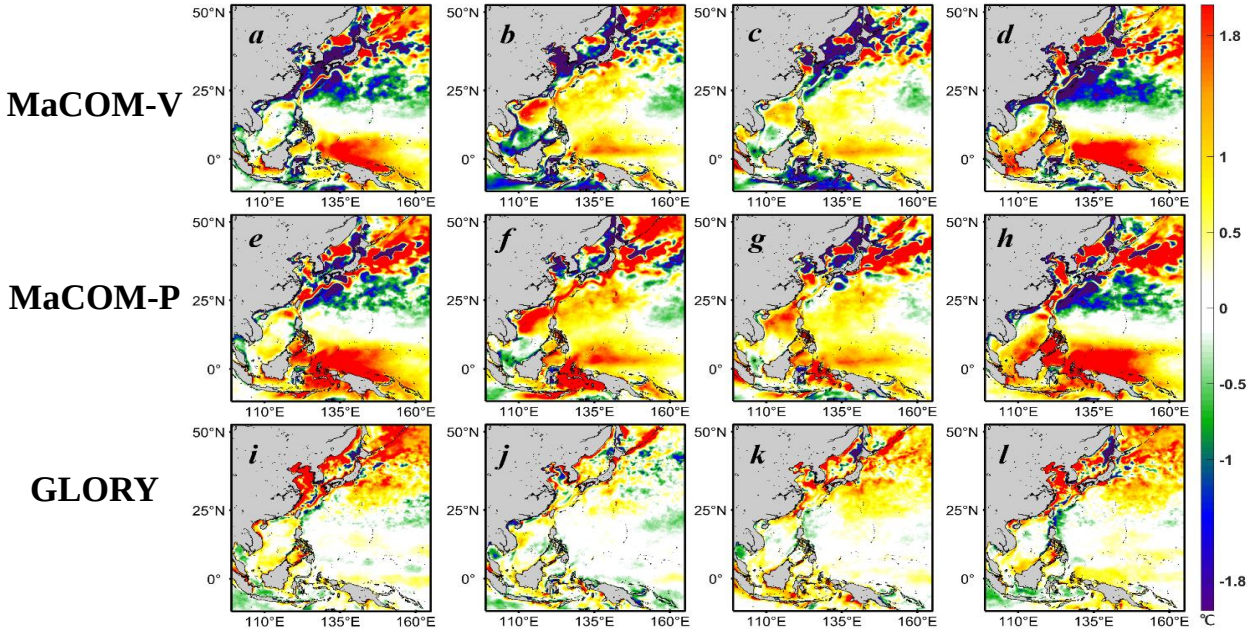


Fig: Seasonally mean distribution of near-climatic error with OSTIA

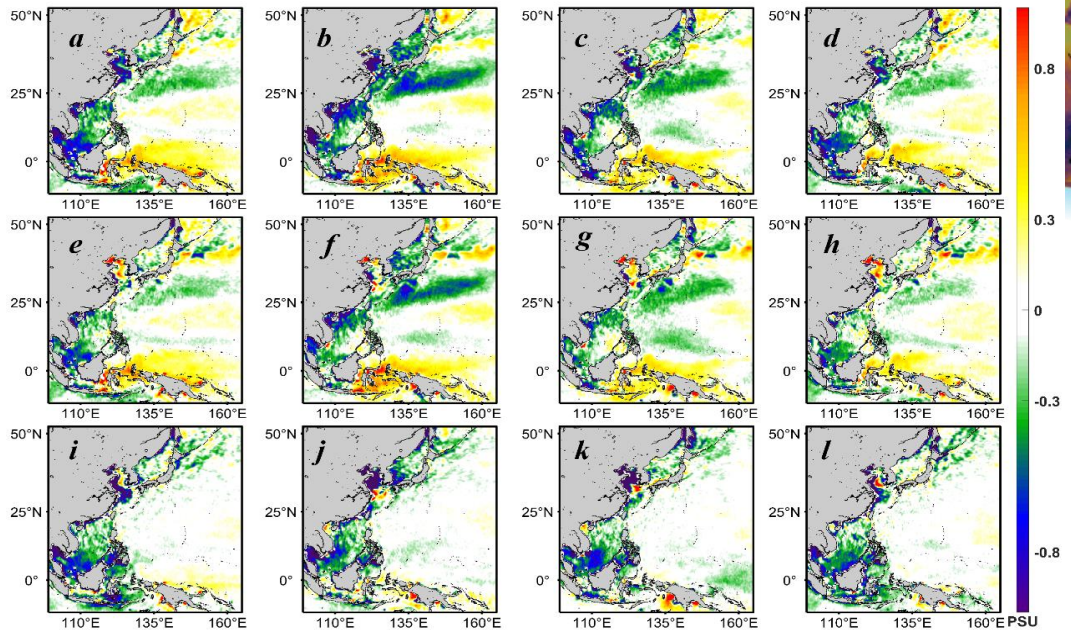


Fig: Seasonally mean distribution of near-climatic error with SMOS

Mon	MaCOM-V	MaCOM-P	GLORY
1	1.0079	1.1095	0.5791
4	0.9228	1.0069	0.5530
7	0.7873	0.8291	0.4903
10	0.7973	0.8376	0.4900
Mean	0.8836	0.9458	0.5290

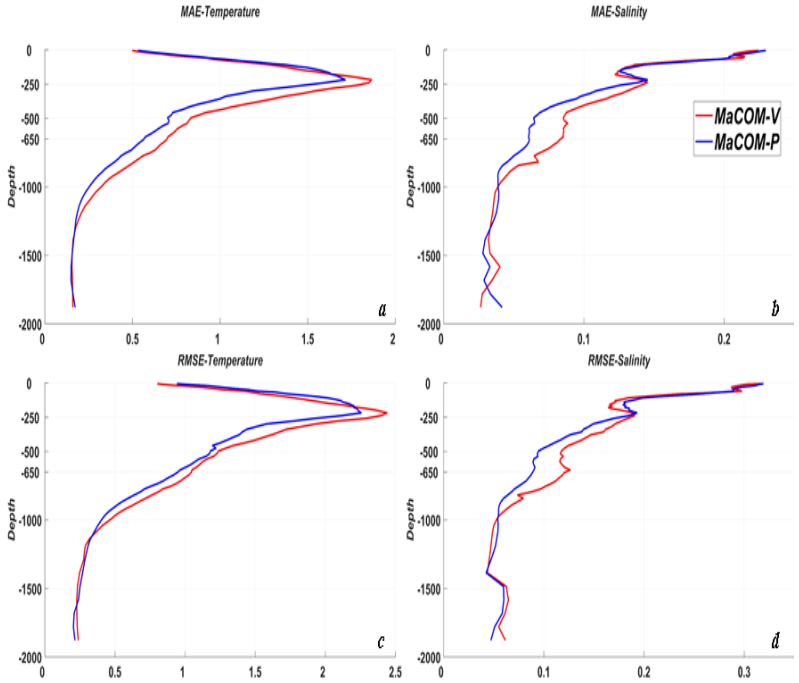
Table:Root mean square error of sea surface temperature(℃)

Mon	MaCOM-V	MaCOM-P	GLORY
1	0.3849	0.3371	0.4536
4	0.4536	0.4093	0.5191
7	0.4539	0.4040	0.6577
10	0.4384	0.4017	0.6557
Mean	0.4331	0.3893	0.5677

Table:Root mean square error of SSS

Hindcast validation: T/S profiles

Fig: The MAE and RMSE of MaCOM and Argo



		T	S
MAE	MaCOM-V	0.846	0.101
	MaCOM-P	0.767	0.093
RMSE	MaCOM-V	1.193	0.140
	MaCOM-P	1.150	0.132

Table:Error of T/S at all levels

MAE RMSE

MaCOM-V

MaCOM-P

GLORY

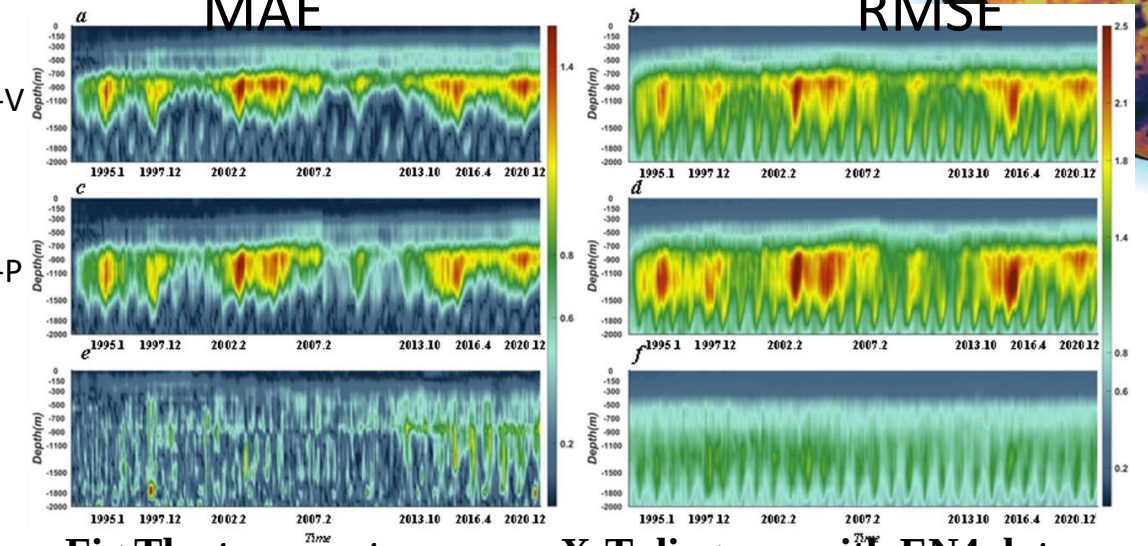


Fig The temperature error X-T diagram with EN4 data

MaCOM-V

MaCOM-P

GLORY

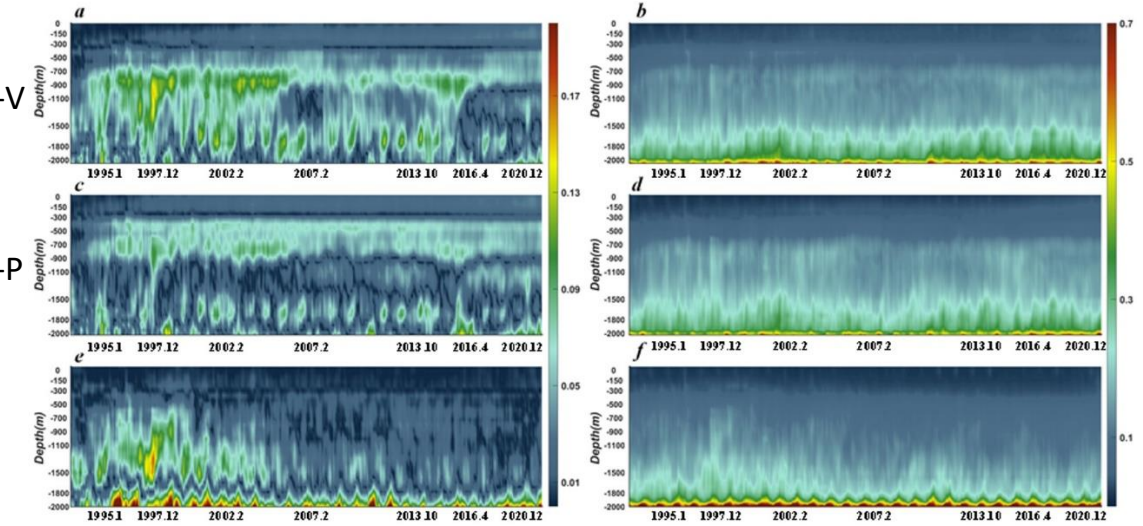
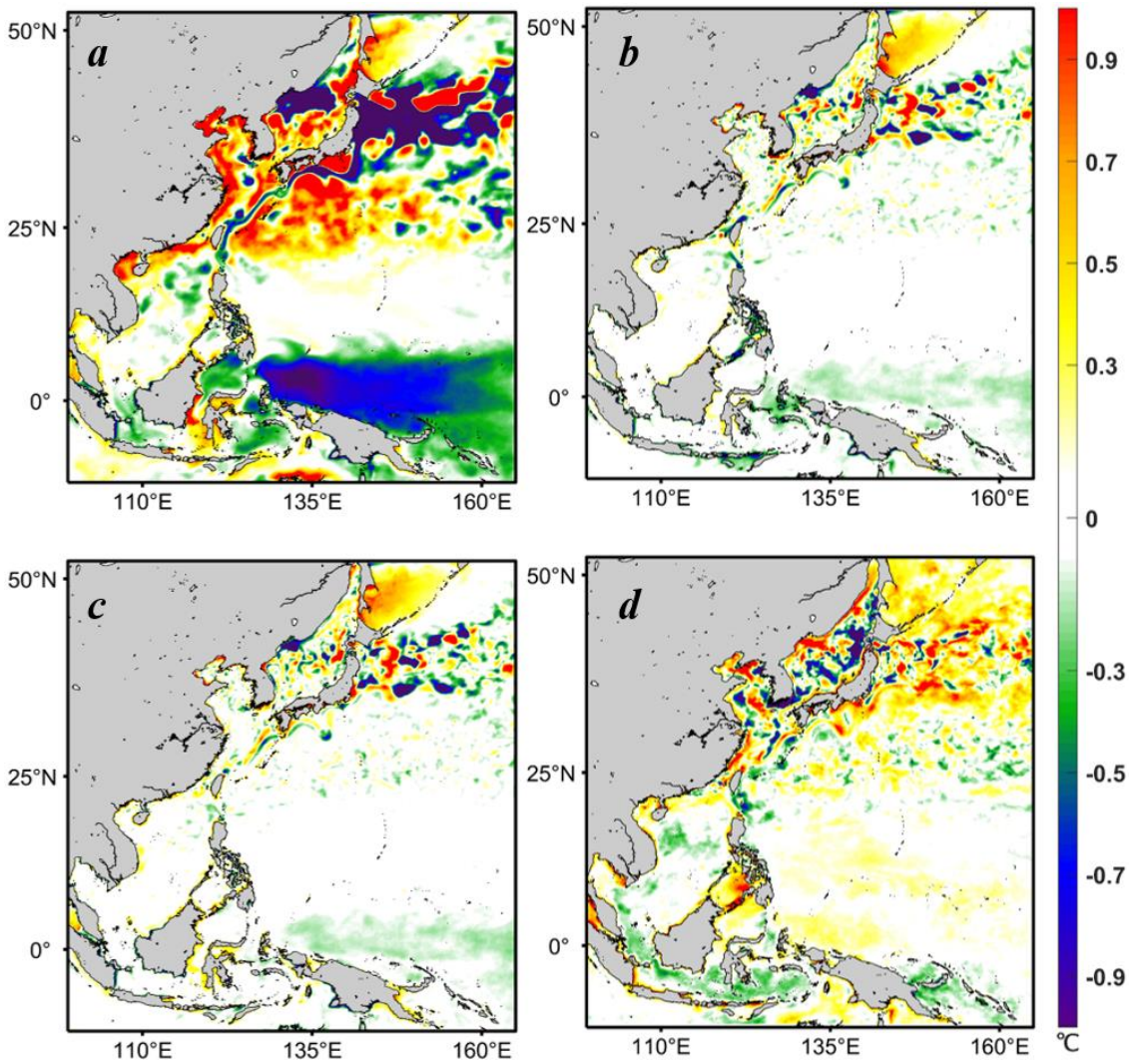
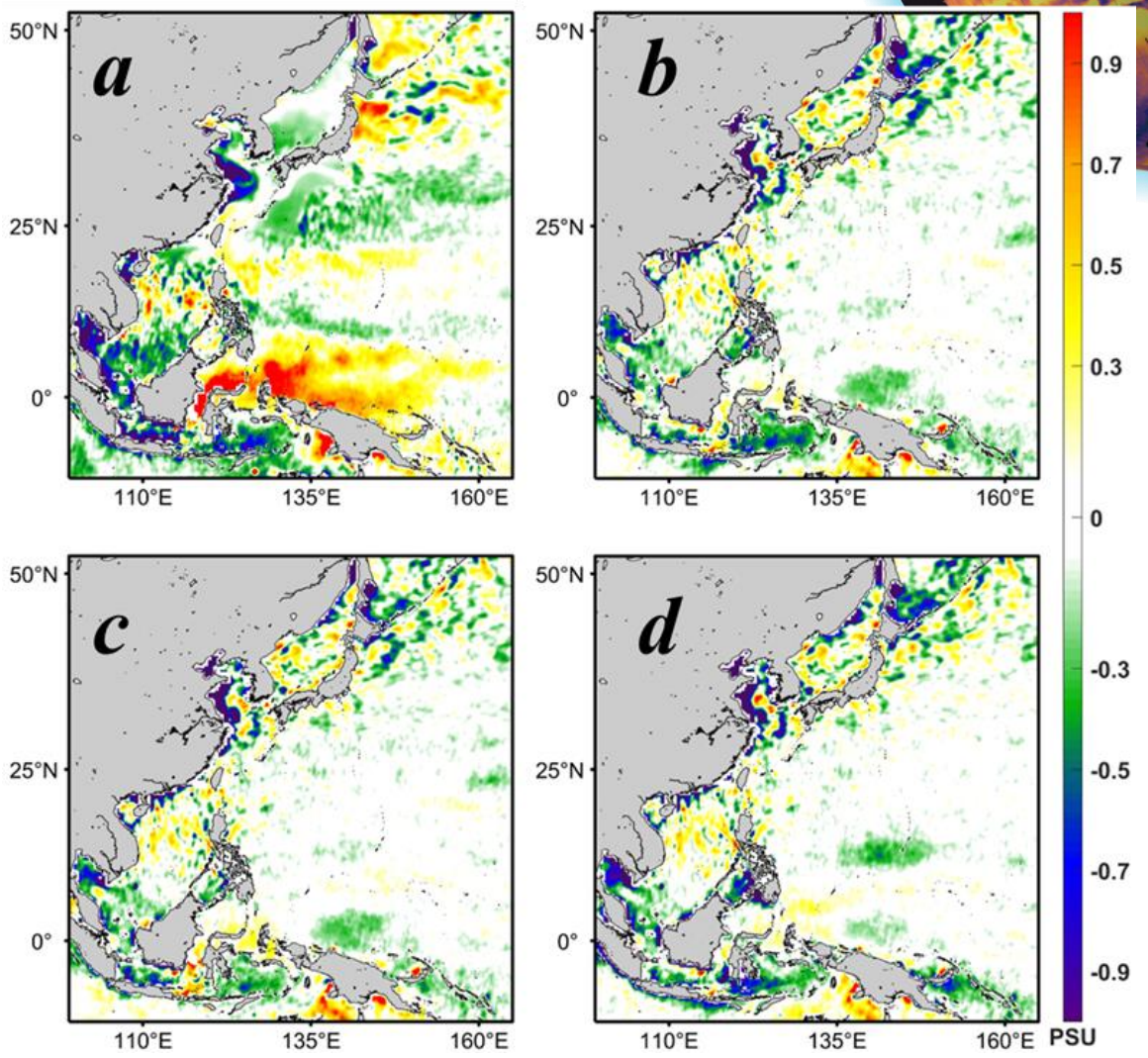


Fig The salinity error X-T diagram with EN4 data

DA validation: SST



Monthly average sea surface temperature error
(a) Ctrl; (b) No tide; (c) Tide; (d) GLORY



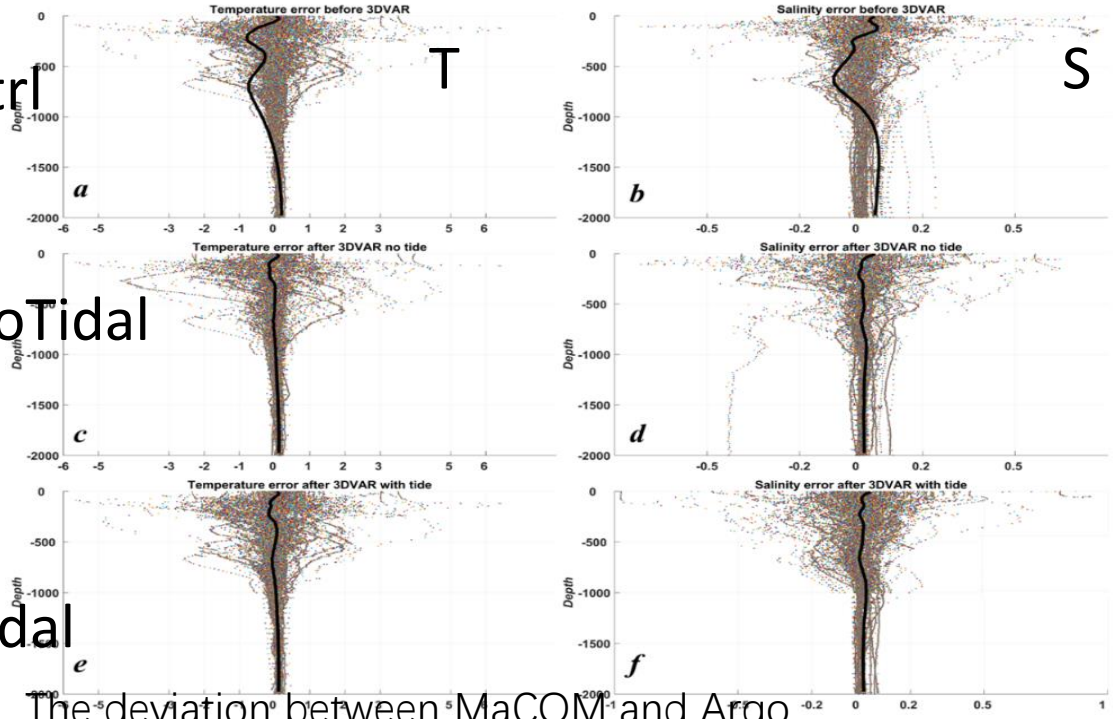
Weekly average sea surface salinity error
(a) Ctrl; (b) No tide; (c) Tide; (d) GLORY

DA validation: T/S profiles

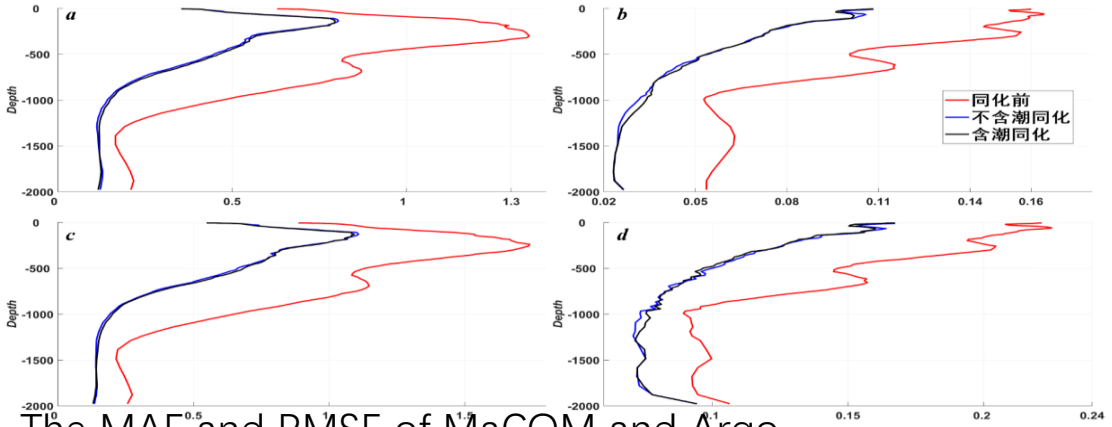
Ctrl

NoTidal

Tidal



The deviation between MaCOM and Argo



The MAE and RMSE of MaCOM and Argo

	T		S	
—\	MAE	RMSE	MAE	RMSE
Ctrl	0.8278	1.0846	0.1119	0.1574
Notial	0.4132	0.5939	0.0594	0.1085
Improvement	50.0%	45.2%	46.9%	31.0%
Tidal	0.4187	0.5981	0.0595	0.1079
Improvement	49.4%	44.86%	46.8%	31.4%

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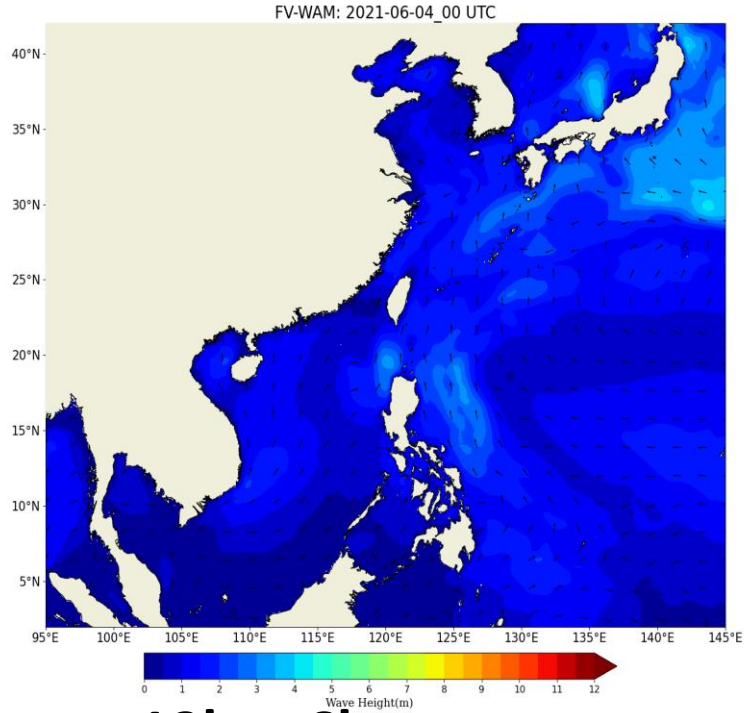
OpenACC Implementation

1. Encapsulating the full FVWAM using OpenACC instructive statements
2. FVWAM can run in workstation or laptop with GPU



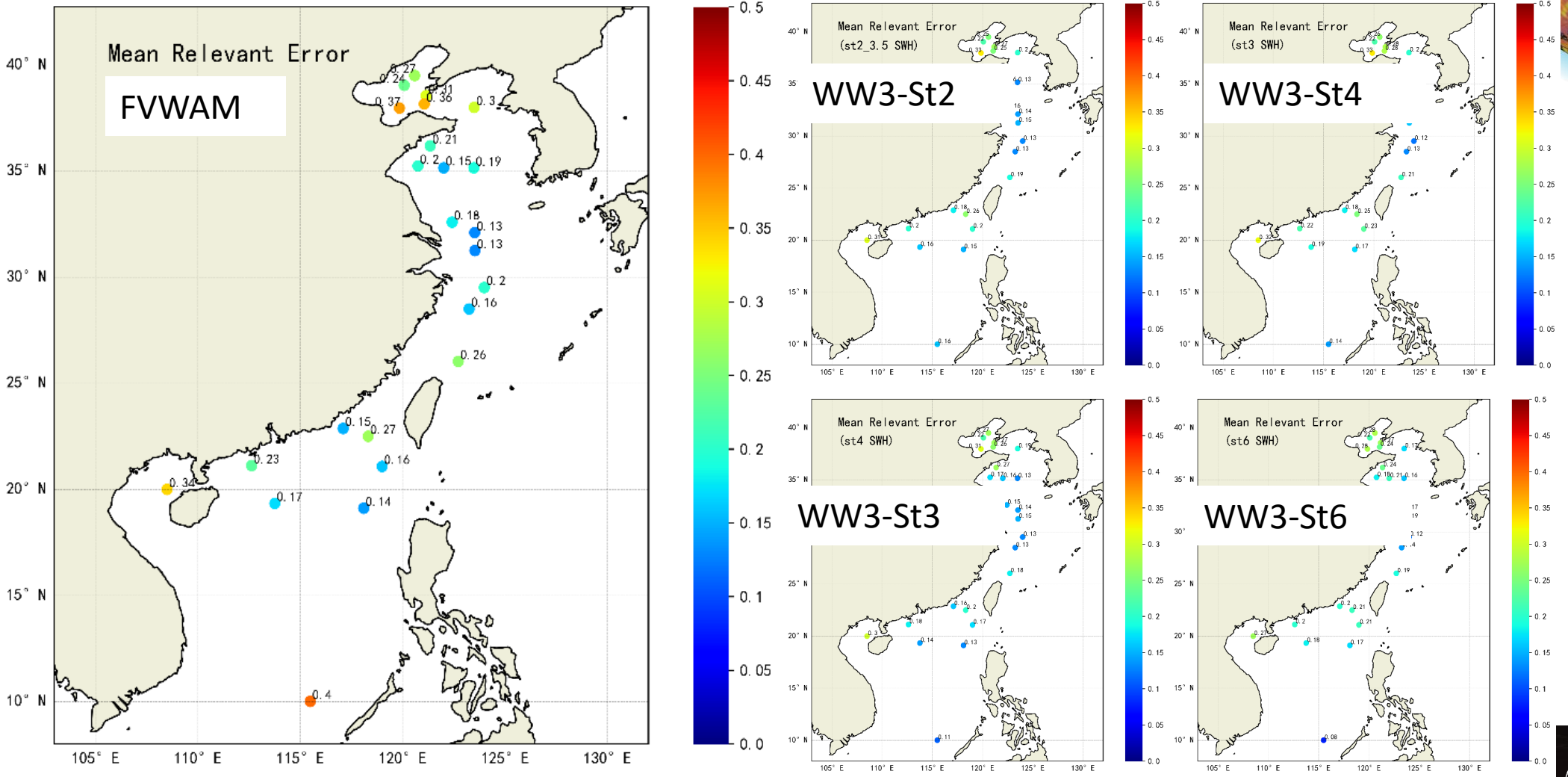
12km-6km

North West Pacific Ocean
Wave Forecast System
GPU: NVIDIA 4000A
Domain: ~95-165°E，5°S-45°N
Space Res: 12km-6km
Spectral Res： 36Dir，35Fre
(f_0 =0.0375，$f_{n+1} = f_n^{1.1}$)
Wind Fields: GRAPES-GFS (NMC) 0.25°
FCST Duration： 7days

Hindcast Verifications

MRE

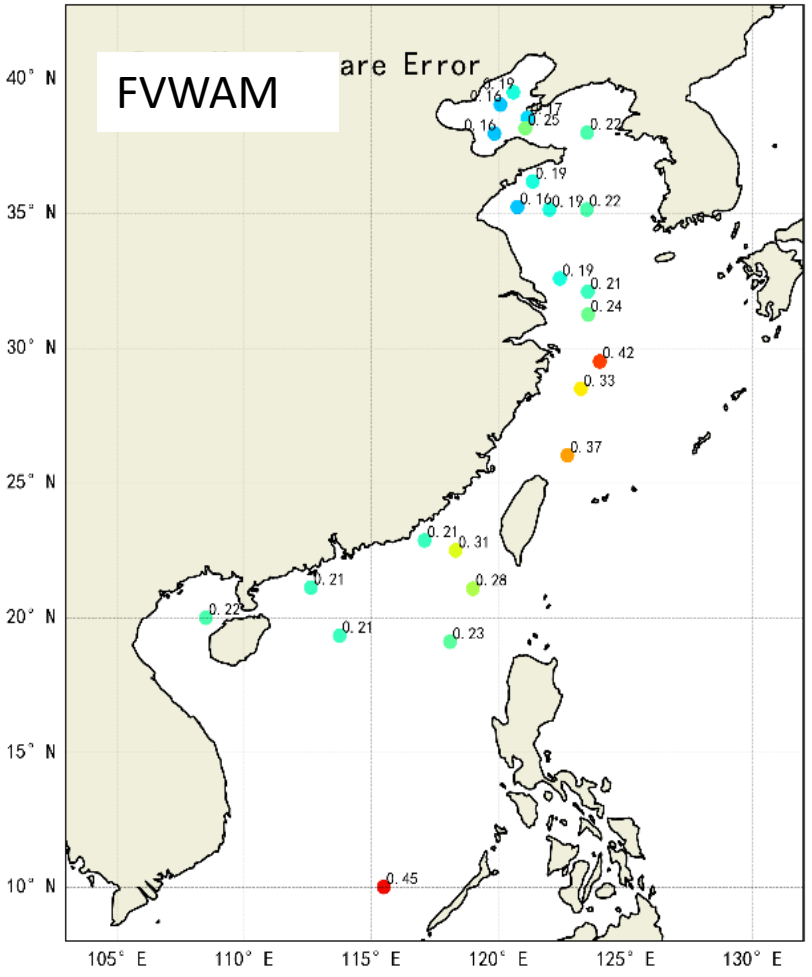
FVWAM Wave in-situ verification （China Buoy）

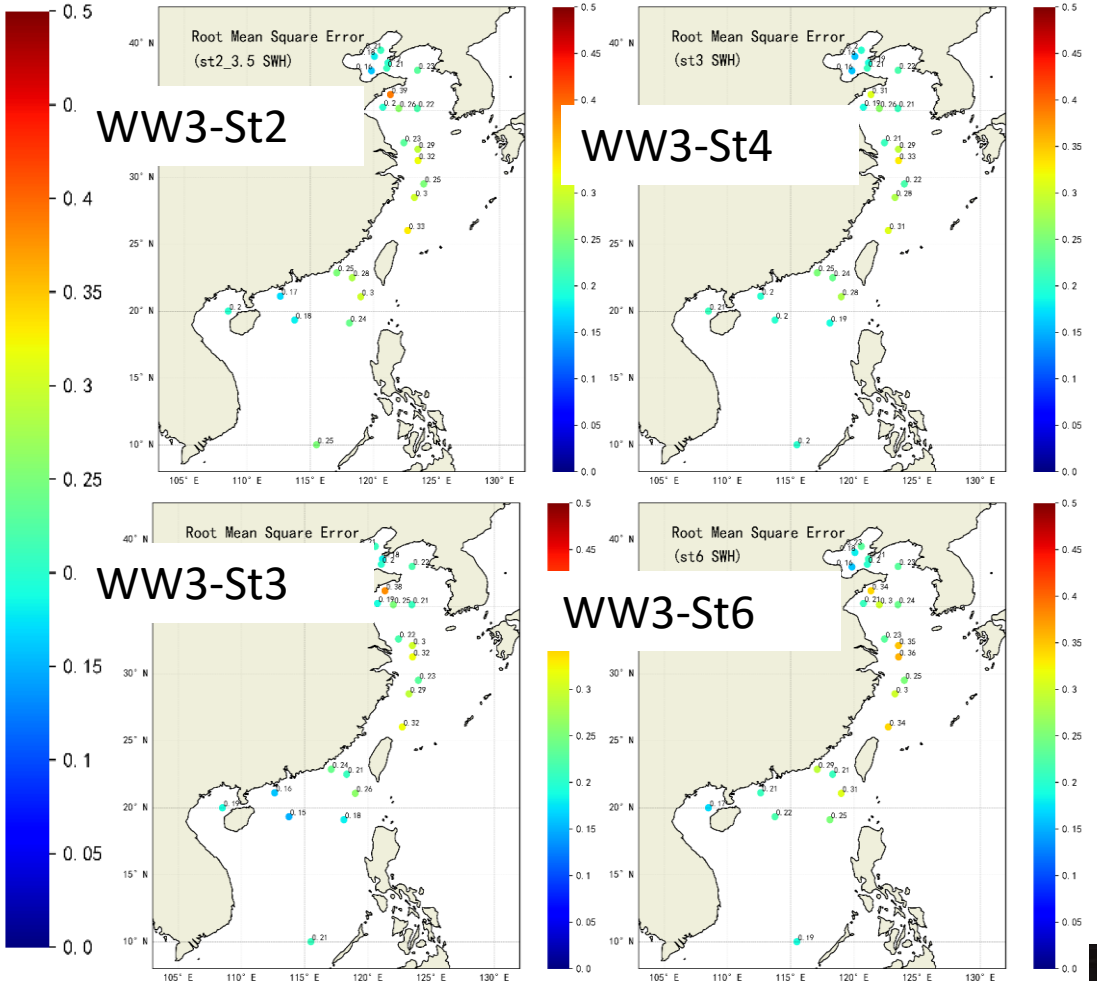


Hindcast Verifications

RMSE

FVWAM Wave in-situ verification （China Buoy）

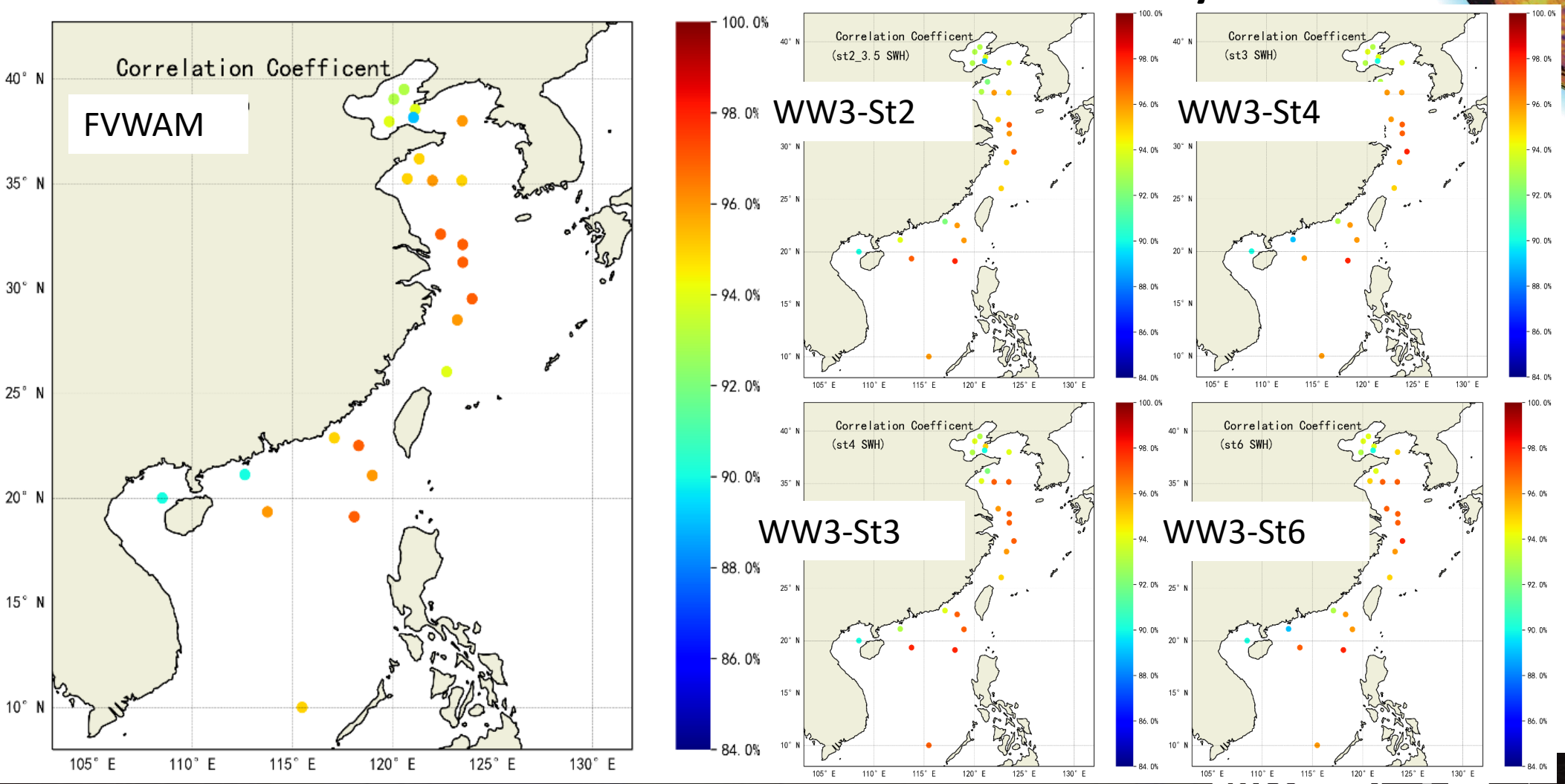




Hindcast Verifications

R

FVWAM Wave In-situ Verification （China Buoy）



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A prediction system with a resolution of 1/24 ° for the Northwest Pacific was constructed based on the MaCOM model, and hindcasts for the mass conservation version and volume conservation version were conducted for 28 model years;

Through validation with various ocean observation and reanalysis data, MaCOM simulation results are relatively accurate, with errors roughly distributed within a reasonable range.

Data assimilation of satellite sea surface temperature data and Argo data in the northwest Pacific Ocean based on 3D-VAR method, and setting up two sets of experiments with and without tides. The assimilation experiment is reasonable and effective, and can significantly reduce the simulation bias of MaCOM.

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