Application and Verification of the Global Wave Intelligent Forecast Model

National Marine Environmental Forecasting Center

Wave Forecasting Division | Hou Fang 2026，04

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Report Outline

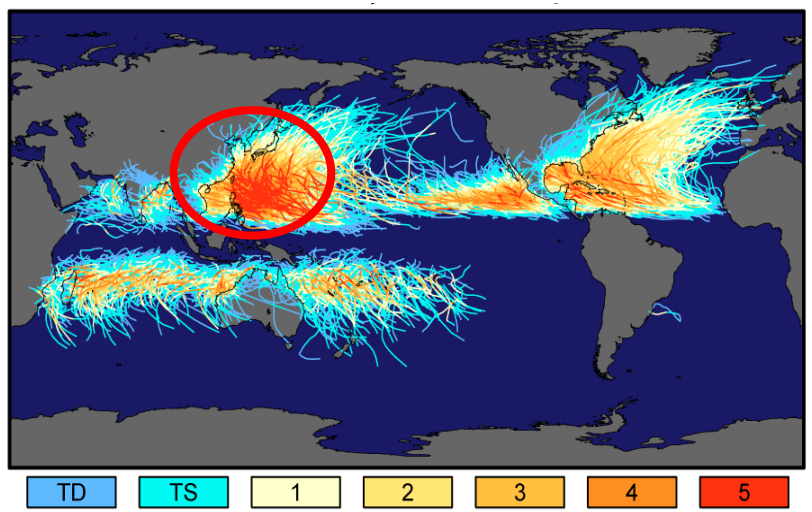
1、Preface and Development Progress

2、Training Data

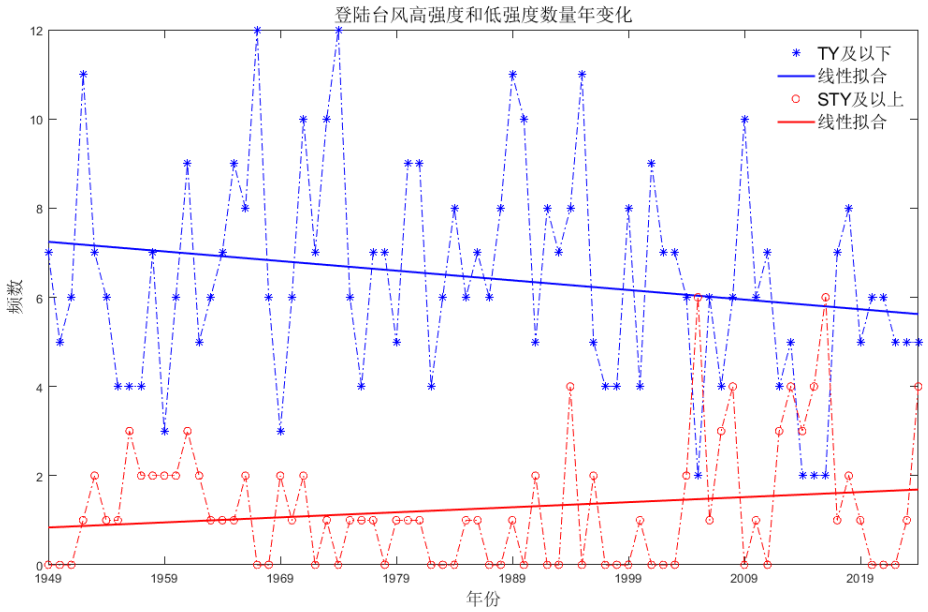
3、Application & Verification

4、Next Work

1、Preface and Development Progress



Annual statistics of typhoon genesis/landfall	(2015-2024)	(1981-2011)
Number of typhoons in the NW Pacific	25.2	25.93
Severe typhoons & above (NW Pacific)	10.5	9.13
Landfalling typhoons	7.0	7.83
andfalling typhoons (Proportion)	27.78%	30.2%
Landfalling severe typhoons & above	1.9	1.0
Landfalling severe typhoons & above (Proportion)	27.14%	12.77%



- Approximately 80–90 tropical cyclones form globally each year, distributed across seven major sea areas: the northwest Pacific and South China Sea, northeast Pacific, Atlantic and Caribbean Sea, southwest Indian Ocean, southwest Pacific, southeast Indian Ocean, and north Indian Ocean. The northwest Pacific and South China Sea are the world’ s most typhoon-active waters, where about 30% of global tropical cyclones develop.
- In the past decade, the number of landfalling severe typhoons and above in China has risen markedly, with the landfall ratio around 14.4% higher than the climatological average.
- China’ s offshore waters are a high-risk zone for wave disasters, affected by typhoons and cold air masses.

1、Preface and Development Progress

Rogue waves are the primary risk to maritime navigation and the deadliest marine hazard, causing the most fatalities and missing persons.

2023年
“鲁蓬远渔028”
沉船事故

5月16日，受热带气旋“法比安”（FABIEN）影响，中国远洋渔船在印度洋倾覆，39位船员全部遇难。

2022年
“福景001”
沉船事故

7月2日，受2022年第3号台风“暹芭”正面袭击，福景001”起重船走锚触碰风机后在南海断裂沉没，25人死亡，1人失踪。

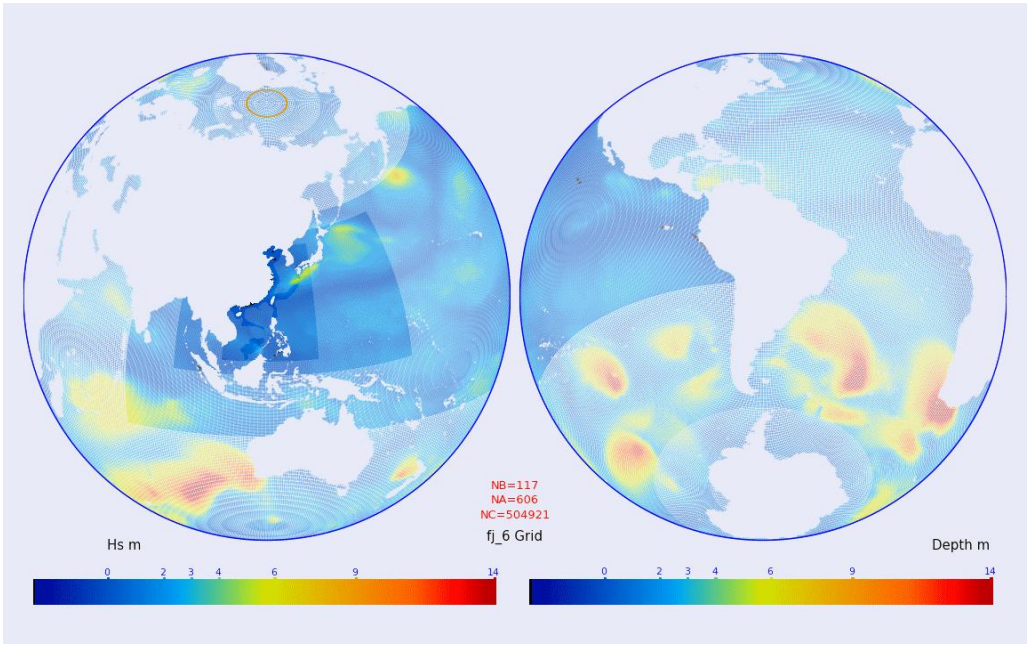
2018年
普吉岛
沉船事故

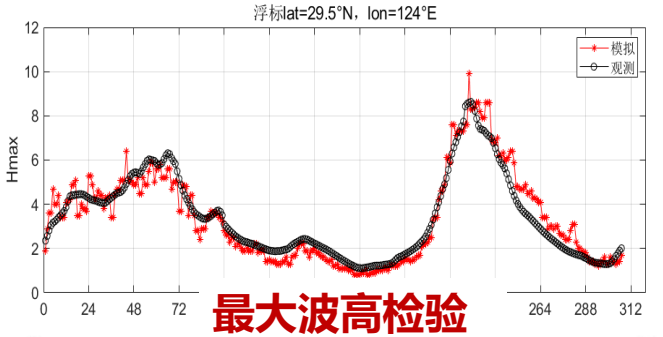
泰国游船“凤凰号” 和“艾沙号”在普吉岛海域遭遇恶劣海况,浪高达5米,船只倾覆并沉没,导致47名中国游客遇难。

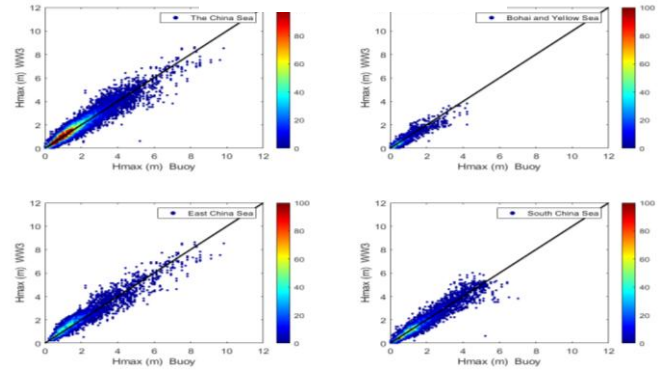
2013年
“9·29西沙”
重大沉船事件

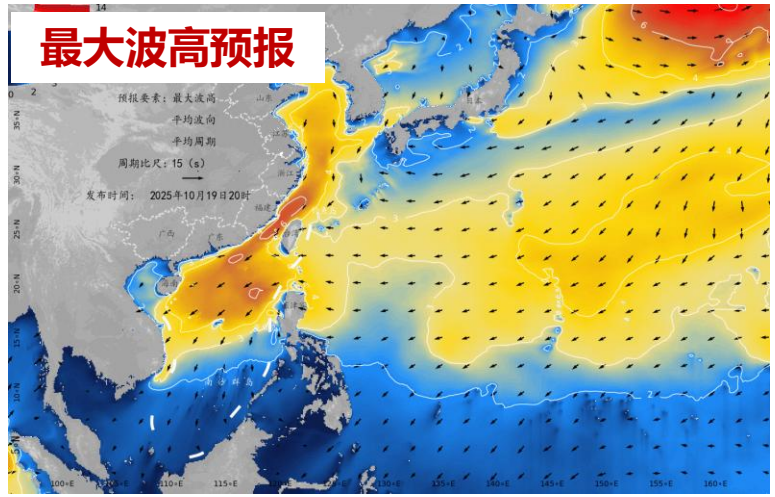
广东台山和香港5艘渔船在南海西沙珊瑚岛附近海域遭受强台风“蝴蝶”袭击，2艘沉没、1艘失去联系，88名渔民遇险，62人遇难或失踪。

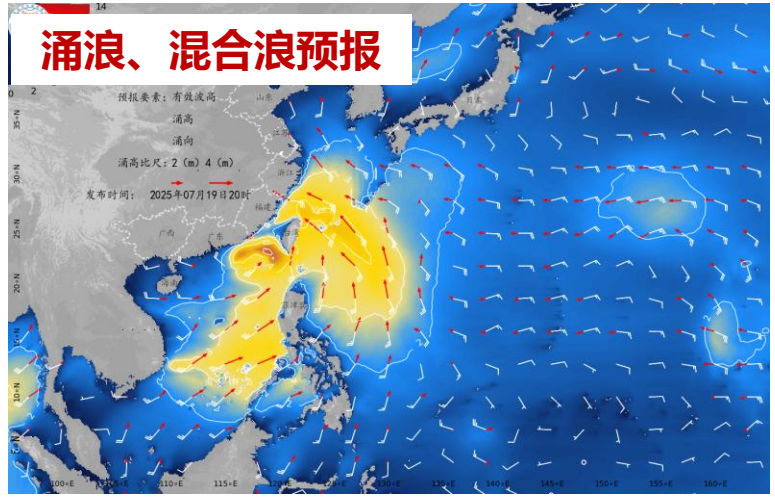
1、Preface and Development Progress





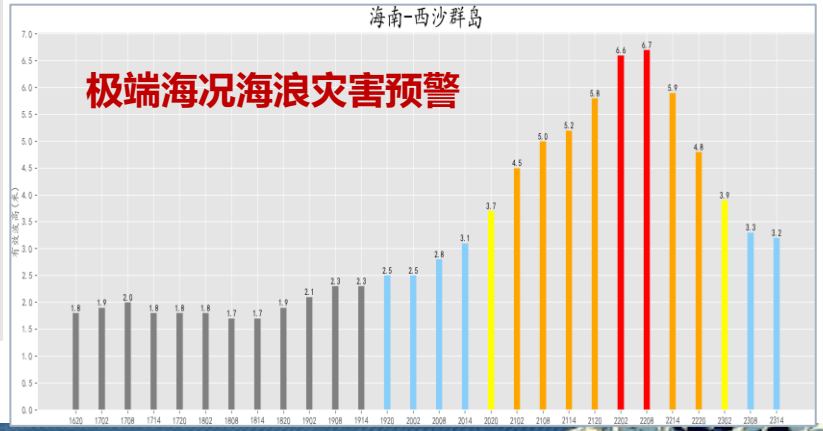






预报时效（h）	平均绝对误差（m）		均方根误差(m)		相对误差RE(%)		相关系数	
	NMEFC	ECMWF	NMEFC	ECMWF	NMEFC	ECMWF	NMEFC	ECMWF
24	0.17	0.2	0.25	0.27	13.61	13.82	0.95	0.96
48	0.19	0.23	0.29	0.31	15.17	15.7	0.94	0.94
72	0.22	0.25	0.33	0.34	17.34	17.72	0.92	0.93
96	0.25	0.28	0.38	0.4	19.59	19.91	0.89	0.9
120	0.28	0.32	0.43	0.45	21.82	21.96	0.86	0.87

预报检验及横评情况



1、Preface and Development Progress

国家海洋环境预报中心 “十四五”海洋预警报业务发展规划

自主化 | 全球化 | 智能化 | 数字化 | 低碳化 | 精细化

The 14th Five-Year Plan period：Intelligent Forecasting Model（global）2021

The 13th Five-Year Plan period：Intelligent Forecasting Model（regional）2018

十二五：研发全球海浪预报系统，并业务化运行；人机交互

十一五：进一步研发中国近海及西北太平洋、浴场海浪业务化数值预报

十五：研发基于WAM/SWAN的中国近海及西北太平洋的深、浅水海浪业务化数值预报系统

八五：引入客观分析和四维同化提高灾害性海浪预报质量

七五：海浪经验预报。自主研制新型混合型海浪数值预报模式开始海浪数值预报

始于1965年

2、Training Data

Forecast Data：

1. ECMWF

0.4°, 6-hourly (before 31 January 2024)

0.25°, 3-hourly (after 31 January 2024)

2. NCEP

0.25°, hourly

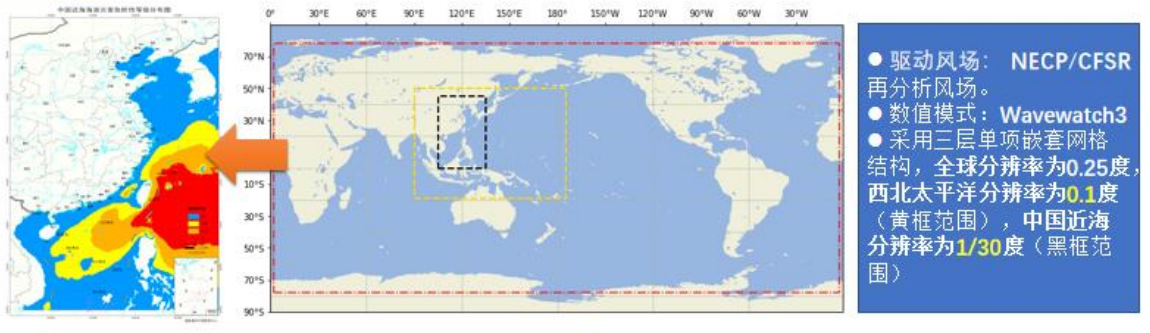
Reanalysis Data:

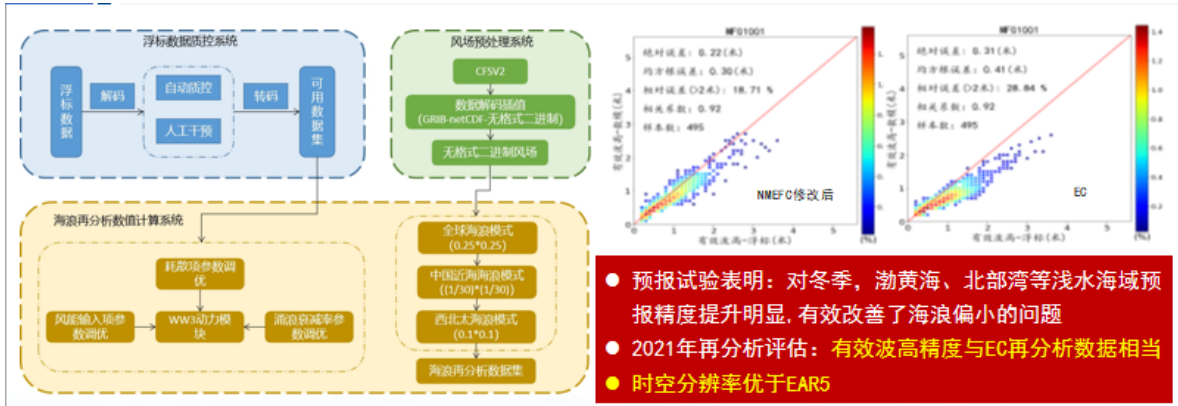
(1)ERA5 (Meteo: 0.25°, Wave: 0.5°, hourly)

(2)NCEP (0.25°) driven, self-developed wave field (0.25° global ~ 1/30° China's coastal waters)

(3) Global wave reanalysis data (ERA5-driven, self-developed wave field, 3 km off the coast)（1994~2025）

(4) China's Greater Bay Area wave reanalysis data (ERA5-driven, self-developed wave field, ~150-300 m off the coast) (1980~2023)





再分析产品	均方根误差（m）	相对误差（Hs>1m）	分散指数（%）	相关系数
NMEFC	0.252	12.24%	20.41	0.962
ERA5	0.264	12.65%	22.96	0.956

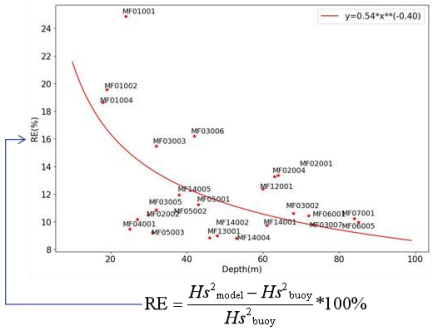
2、Training Data

New Wave Hindcast Dataset

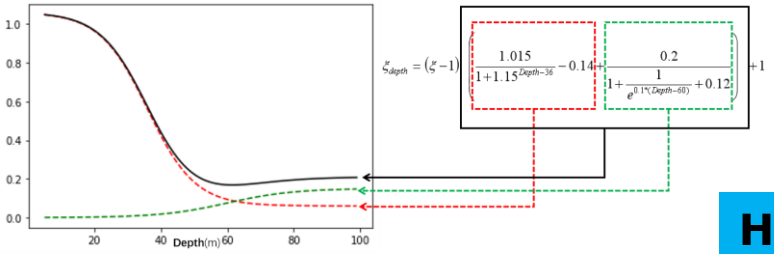
Atmospheric stratification instability on wave growth was considered to optimize the self-developed parameterization scheme; a global-to-regional reanalysis system was reconstructed (0.5° for open ocean, 3 km for global/China's coastal & nearshore waters).

$$\xi = C_1 * U_{10}^{C_2} * Sign(T_{2m} - SST) * \left(|T_{2m} - SST| + C_3\right)^{C_4} + C_5$$

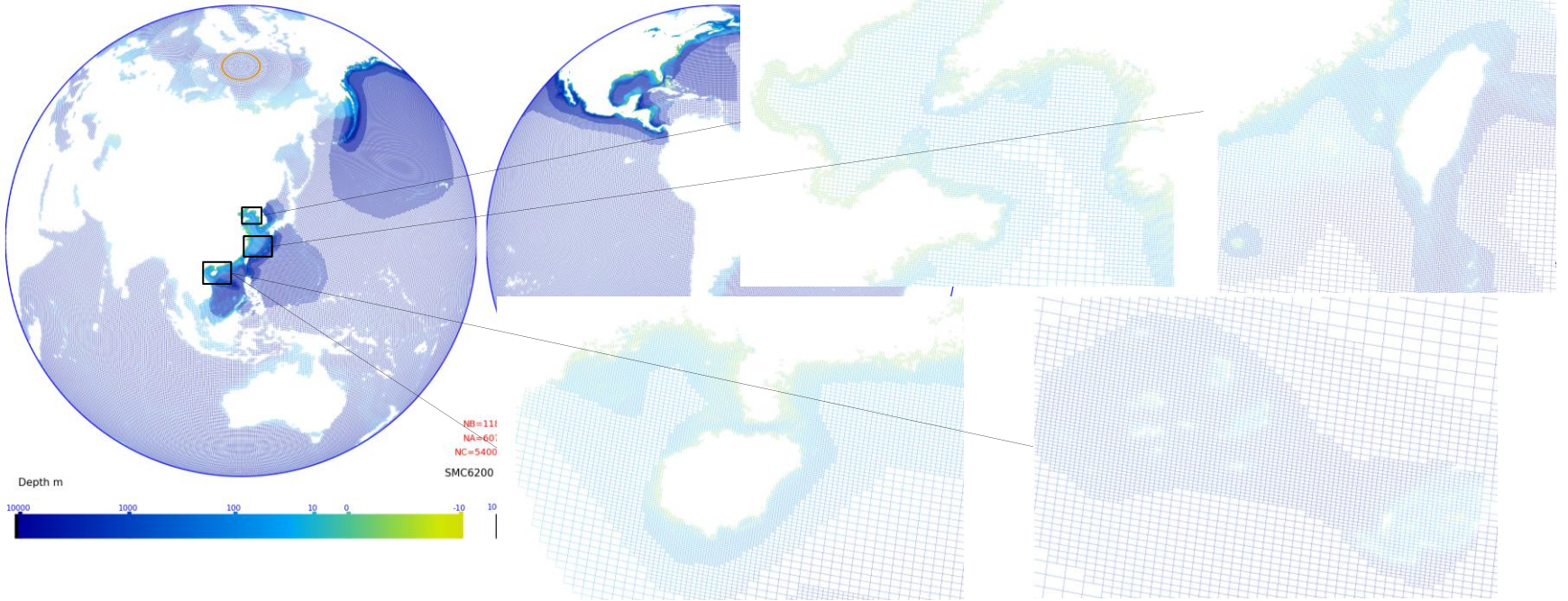
$$u_* = u_* * \xi$$



$$RE = \frac{Hs^2_{model} - Hs^2_{buoy}}{Hs^2_{buoy}} * 100\%$$



$$\xi_{adepth} = (\xi - 1)\left(\frac{1.015}{1+1.15^{Depth-36}} - 0.14 + \frac{0.2}{1+\frac{1}{e^{0.1*(Depth-60)}}} + 0.12\right) + 1$$

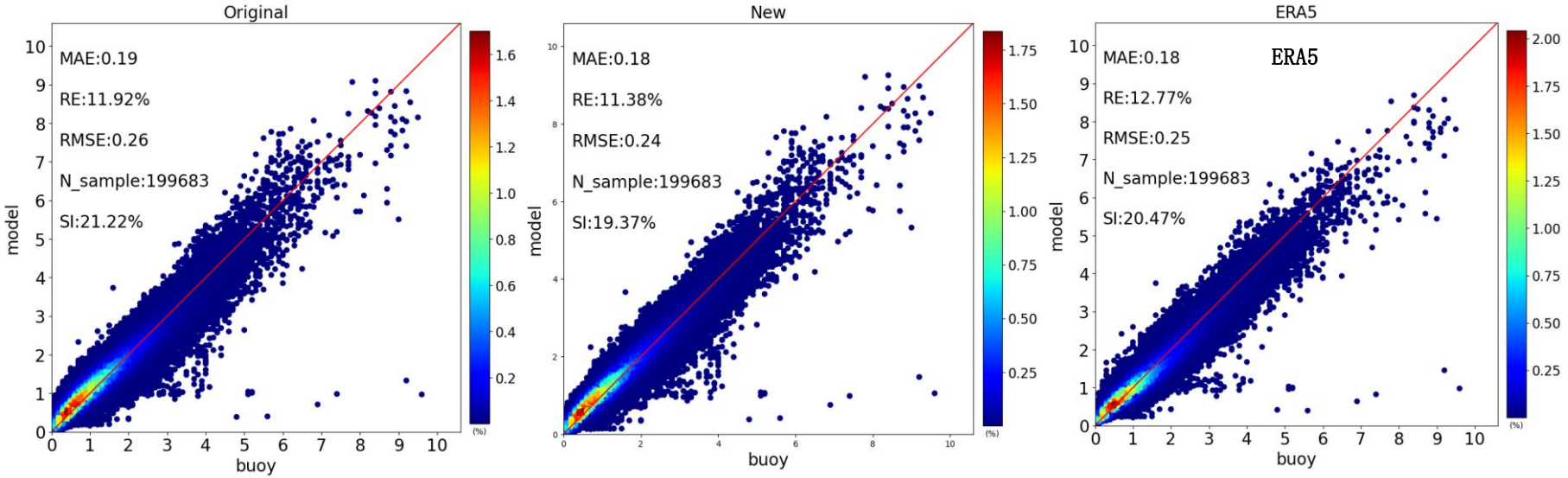


Hou F（2024）5th workshop on waves and wave-coupled processes[Conference Report]. The effect of atmospheric instability on wave growth.Reading, UK.

2、Training Data

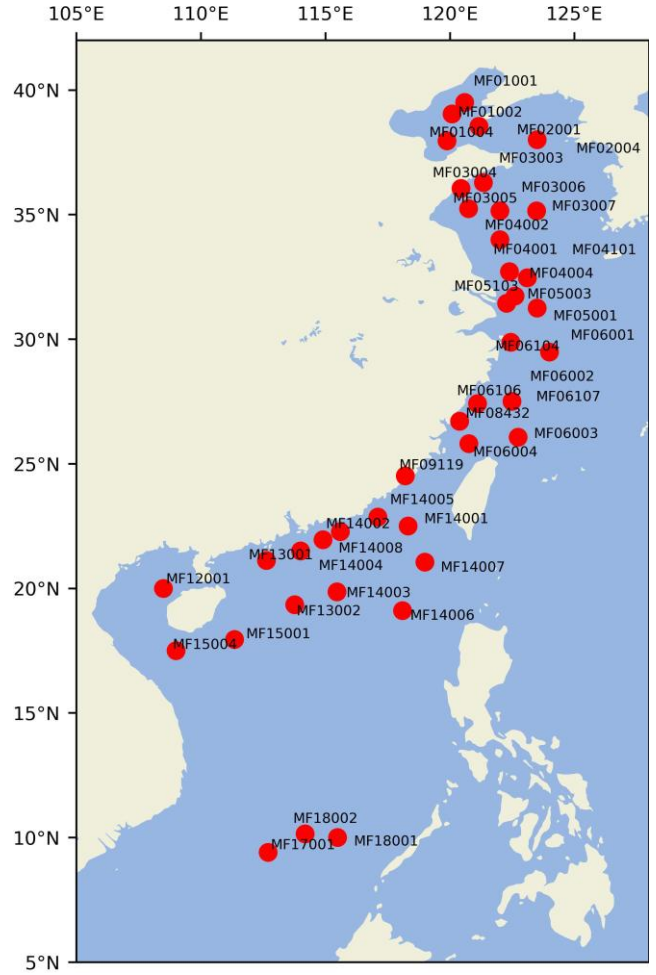
Buoy Verification in China's Coastal Waters and Cross-Comparison with ERA5

(Hindcast Results VS ERA5)



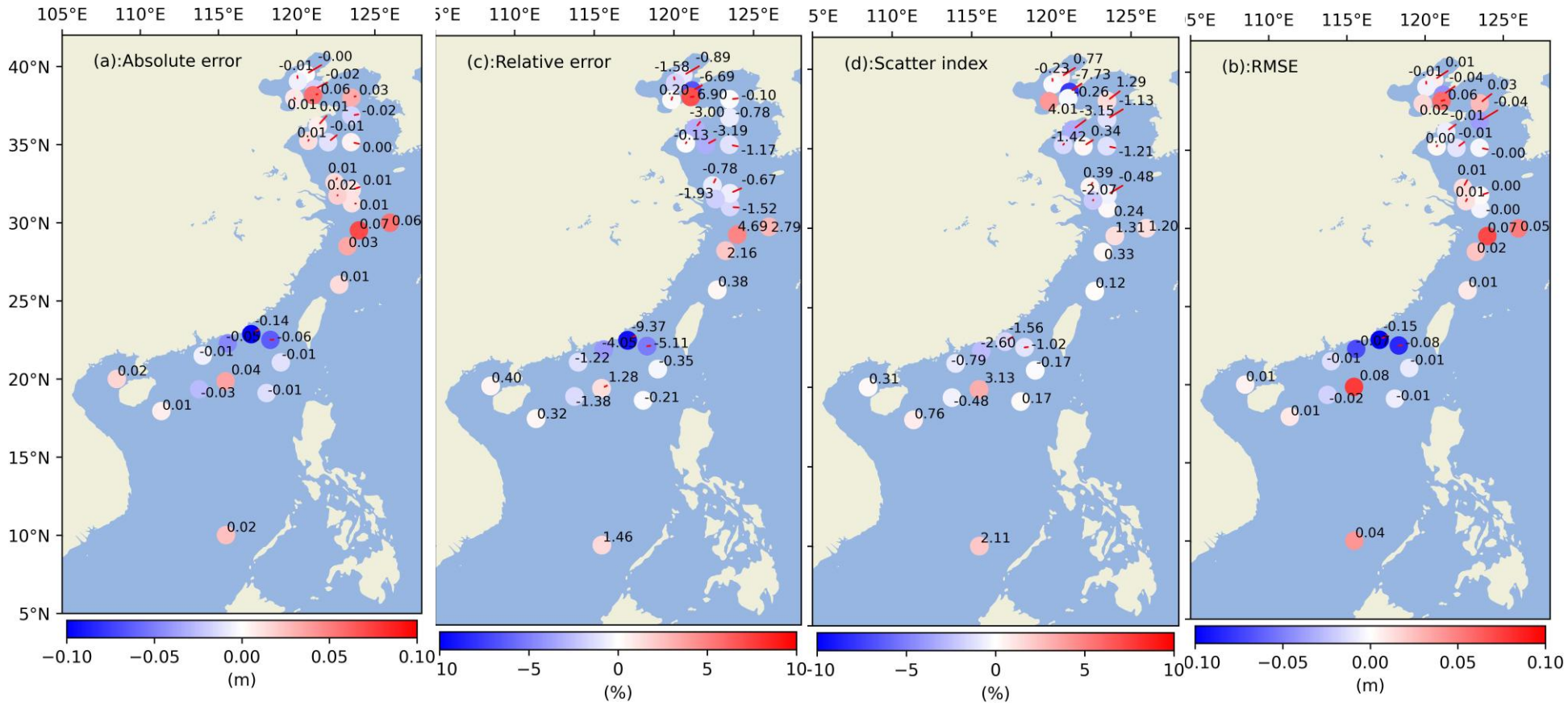
	MAE (m)	RMSE (m)	Relative Error (Hs>1m)	SI (%)
Original	0.19	0.26	11.92%	21.22
New	**0.18**	**0.24**	**11.38%**	**19.37**
ERA5	0.18	0.25	12.77%	20.47

- A one-year long-term time-series verification was conducted using the buoy observations in the coastal waters of China.
- Results of the new parameterization scheme in hindcast outperform the original one significantly, and also show a slight advantage over ERA5.



2、Training Data

Buoy Verification in China's Coastal Waters and Cross-Comparison with ERA5



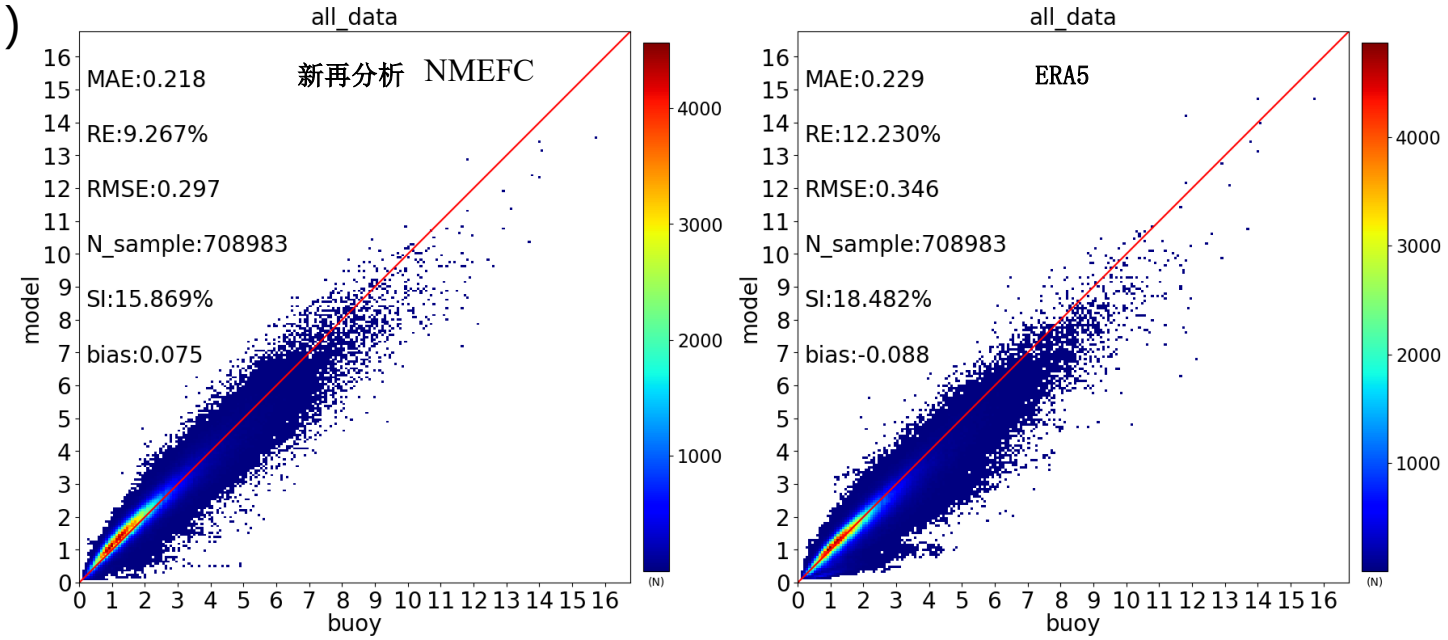
Values: Error difference (Our Center's product – ERA5 product)

Color Coding: Blue = Smaller error (Our Center); Red = Smaller error (ERA5)

Key Finding: Our products show clear advantages in the northern South China Sea (based on error spatial distribution).

2、Training Data

Verification of NDBC Buoys and Cross-Comparison with ERA5 Reanalysis Data（Hindcast Results VS ERA5）

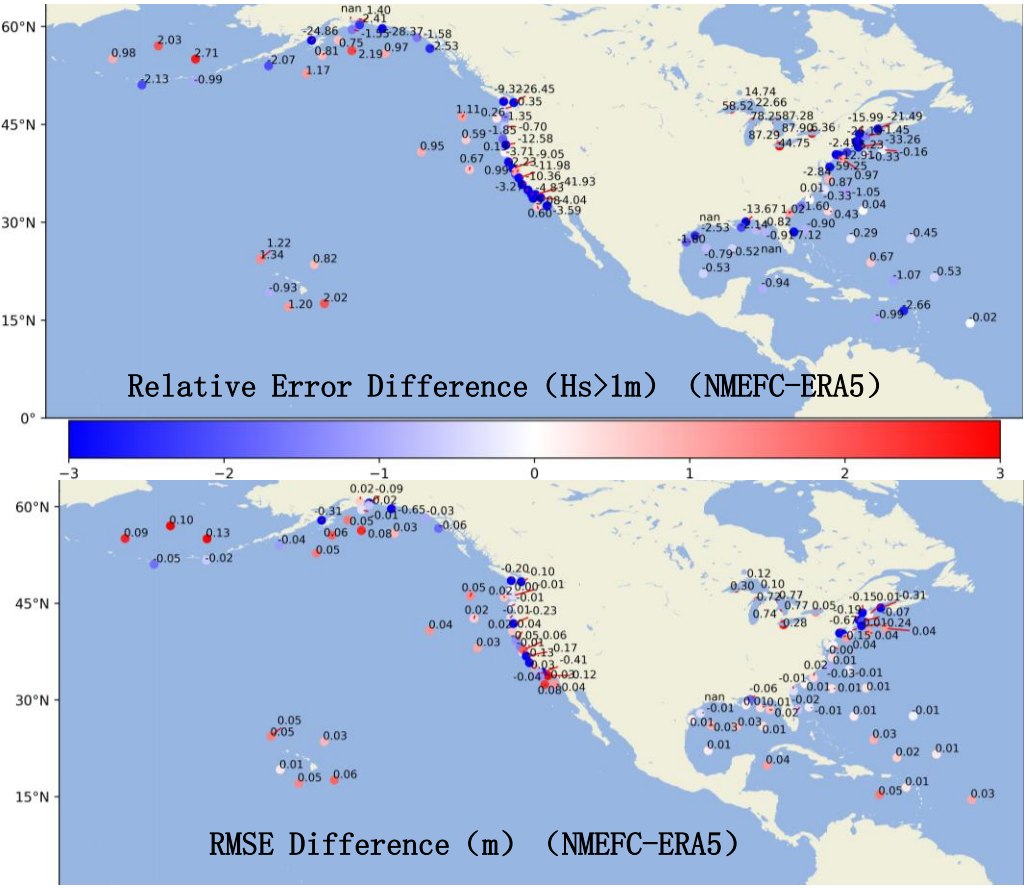


	MAE（m）	RMSE（m）	Relative Error (Hs>1m)	SI（%）	MAE（m）
NMEFC	0.218	0.297	9.2673%	15.869	0.075
ERA5	0.229	0.346	12.230%	18.482	-0.088

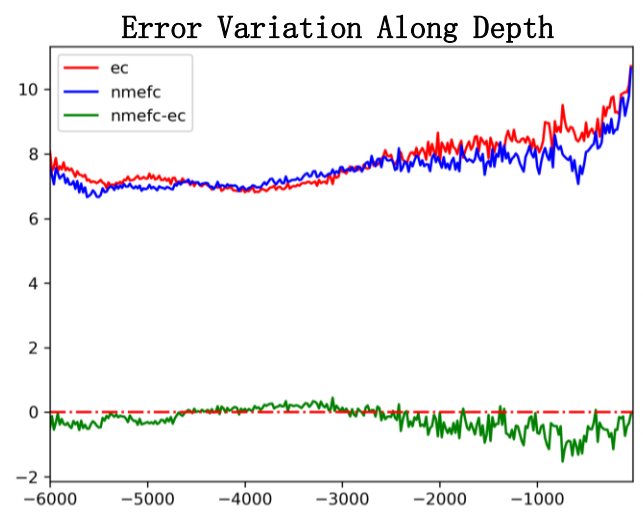
A one-year long-term verification was conducted using observations from 84 NDBC buoys.

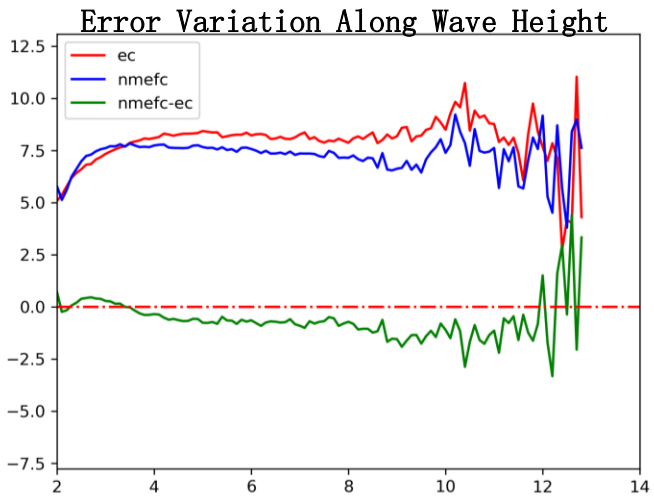
All error metrics outperform ERA5.

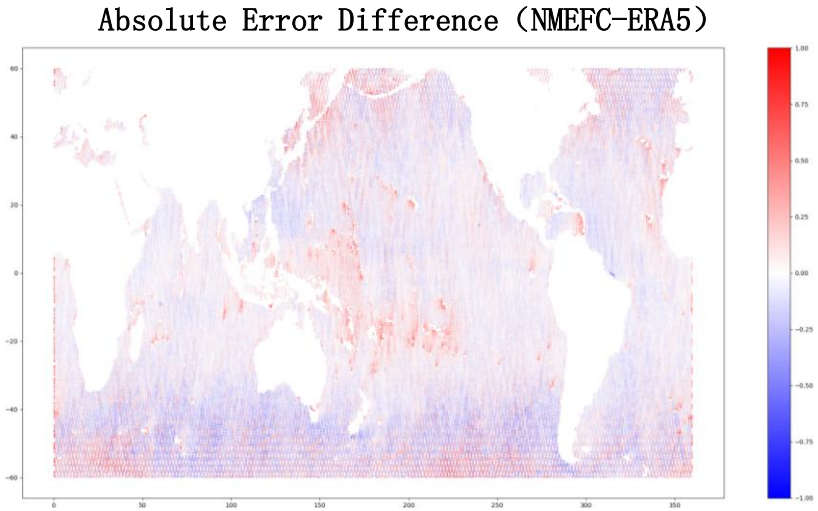
2、Training Data



Cross-Comparison Results of Individual Buoys with ERA5





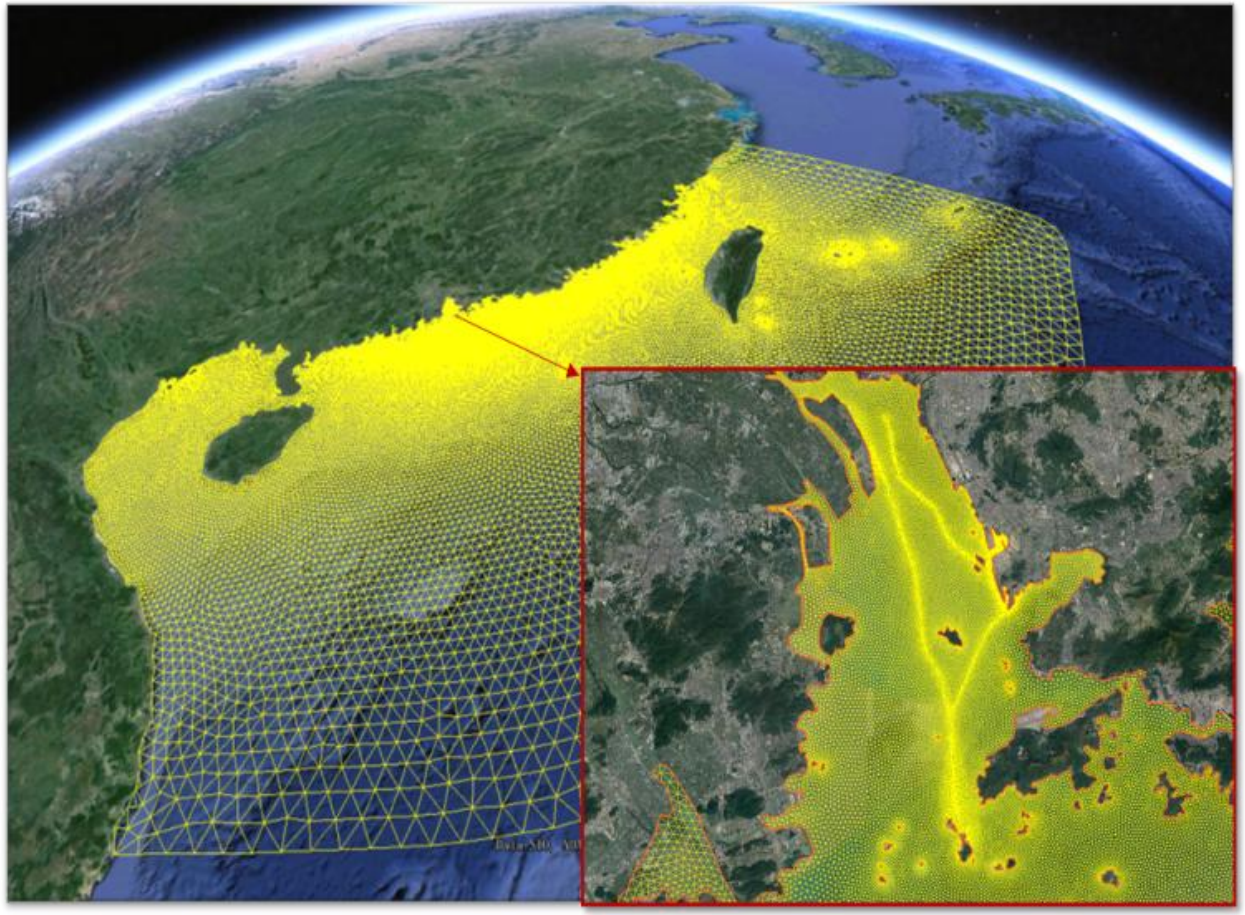


Cross-comparison was conducted against CFOSAT altimeter data

- ✓ NMEFC performs better in waters <3000 m and >4500 m, especially <1000 m.
- ✓ NMEFC outperforms in high-value regions but overestimates at 2–3 m.

2、Training Data

China’s Greater Bay Area wave reanalysis data



(1) Output Data

Hourly outputs of Hs, Dir, TM01, TM02; and half-hourly outputs of water level and current velocity.

Data period: 1980-2022 (43 years in total).

(2) Observation Data

Tide gauge stations: Dawanshan, Zhuhai, Chiwan

Buoys: SF301, QF308, QF305

Wind observation stations of Hong Kong-Zhuhai-Macao Bridge: Guishan Island, West Artificial Island, East Artificial Island

Wave observation stations in the bay: 4 stations (b1, b2, b4, b5)

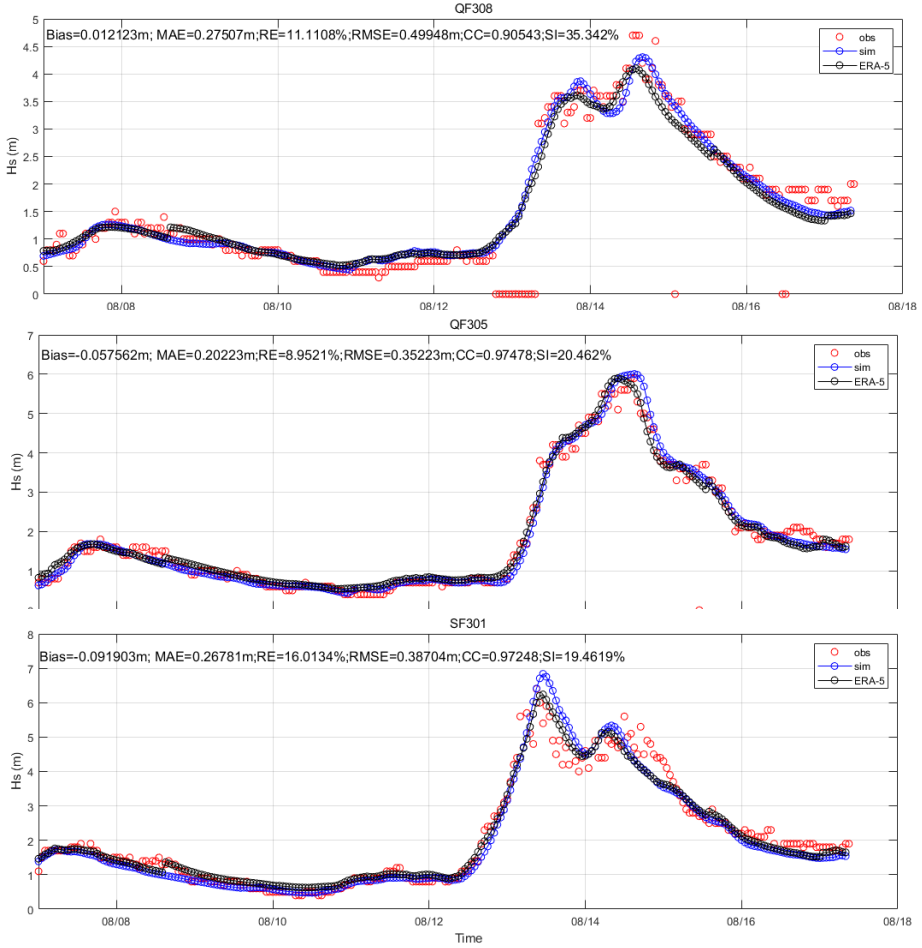
(3) Forcing Field

ERA-5 sea surface wind and pressure, 0.25° resolution, hourly.

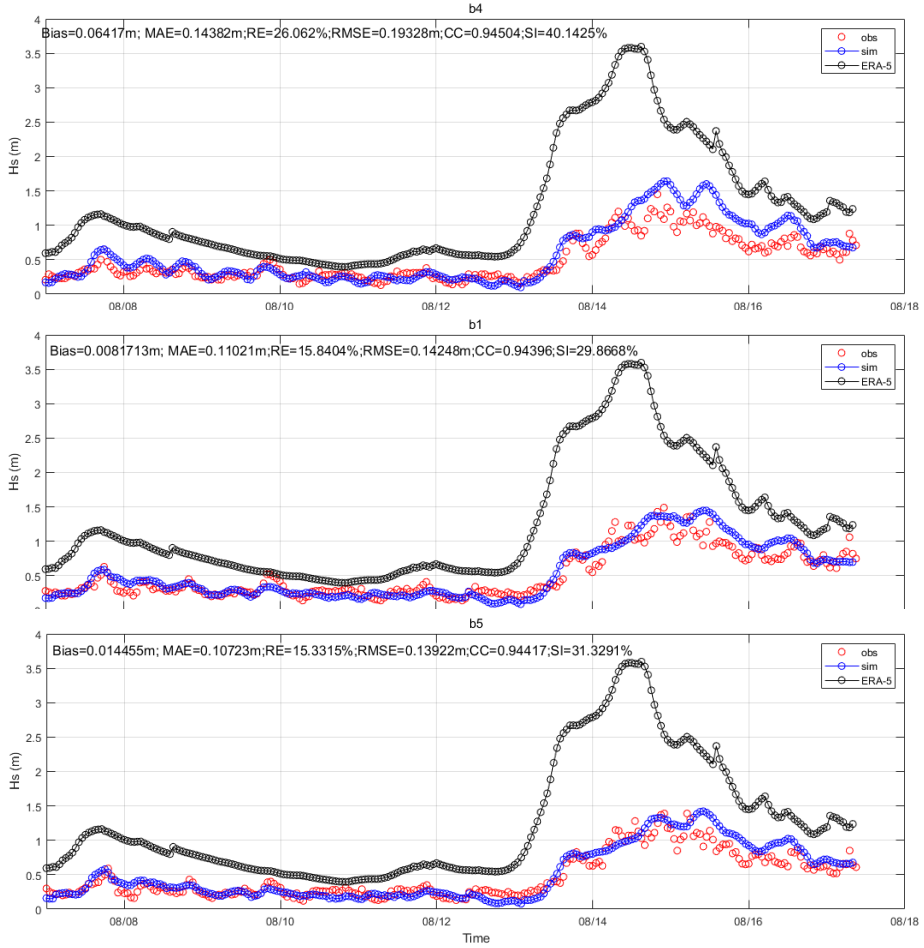
2、Training Data

Process Cross-Comparison (Typhoon Utor, 201311)

Accuracy of offshore simulation is comparable to that of ERA5.

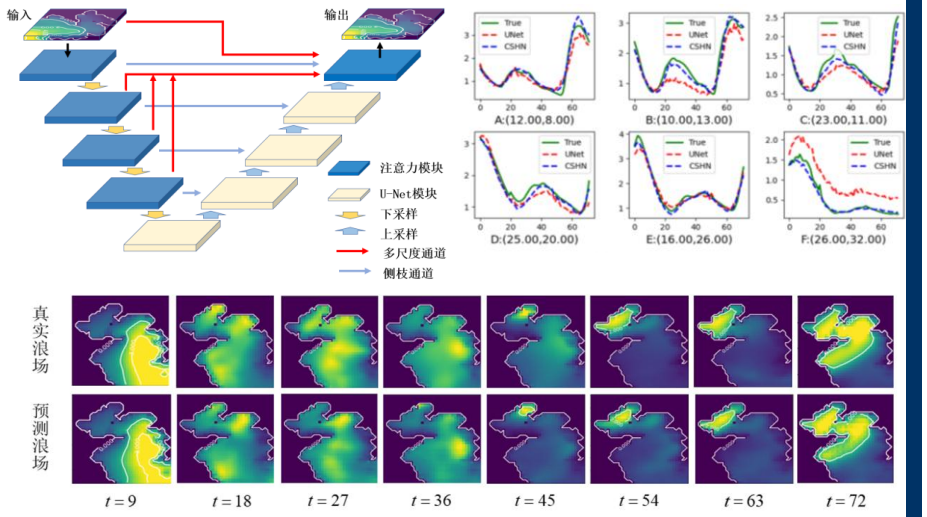


ERA5 cannot accurately simulate the bay's wave height distribution due to resolution limits.

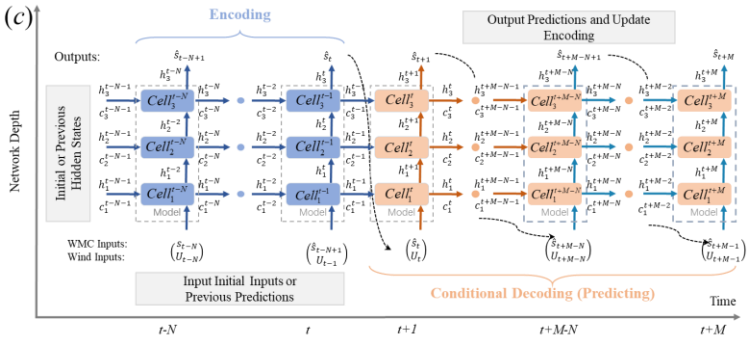


3、Application & Verification

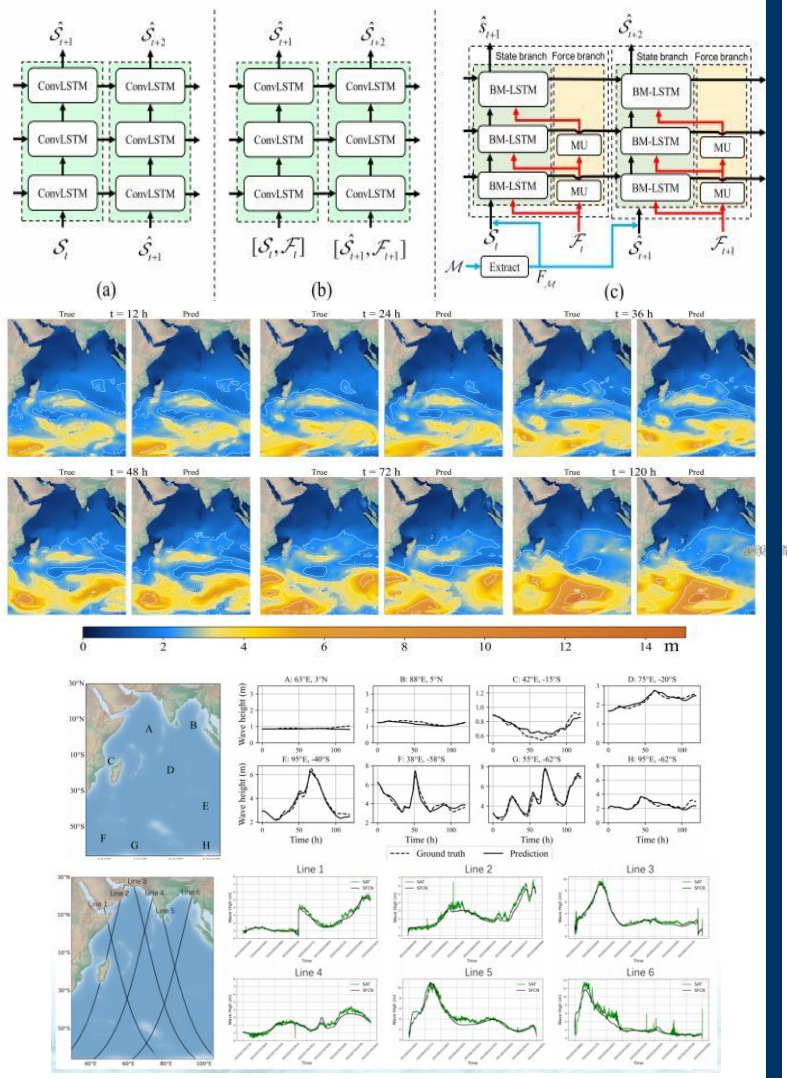
CSHN（基于Unet）



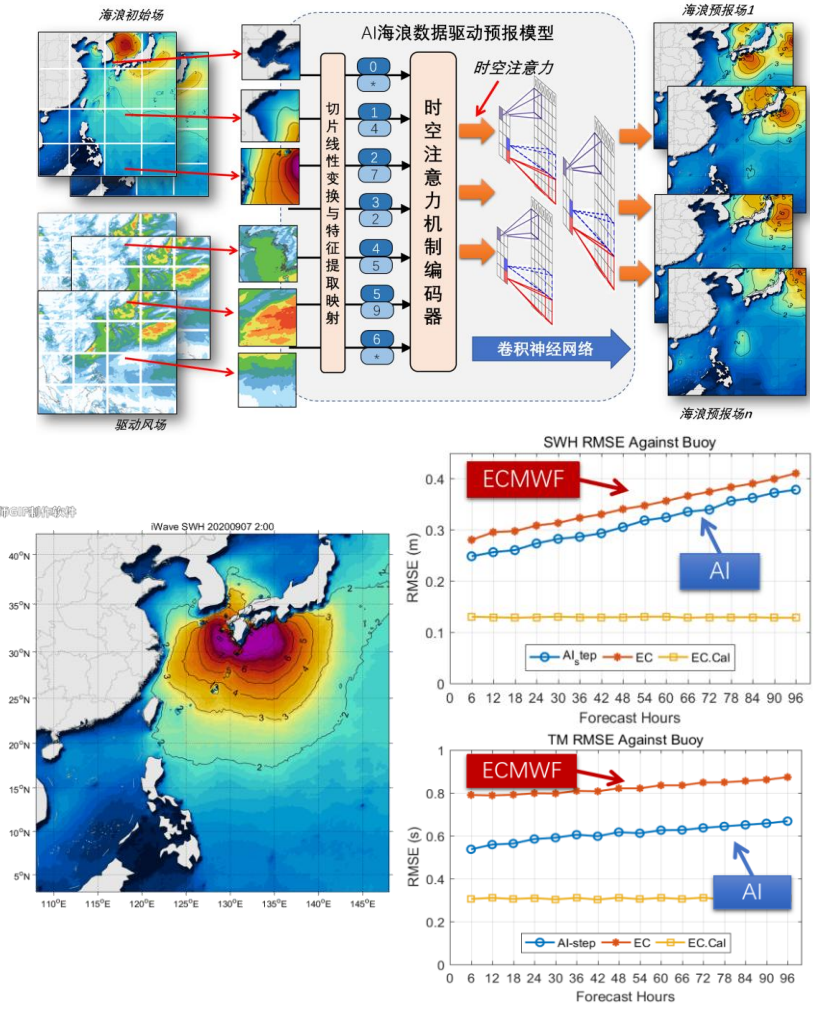
DFF-ConvLSTM（Driving Fileds Forced-ConvLSTM）



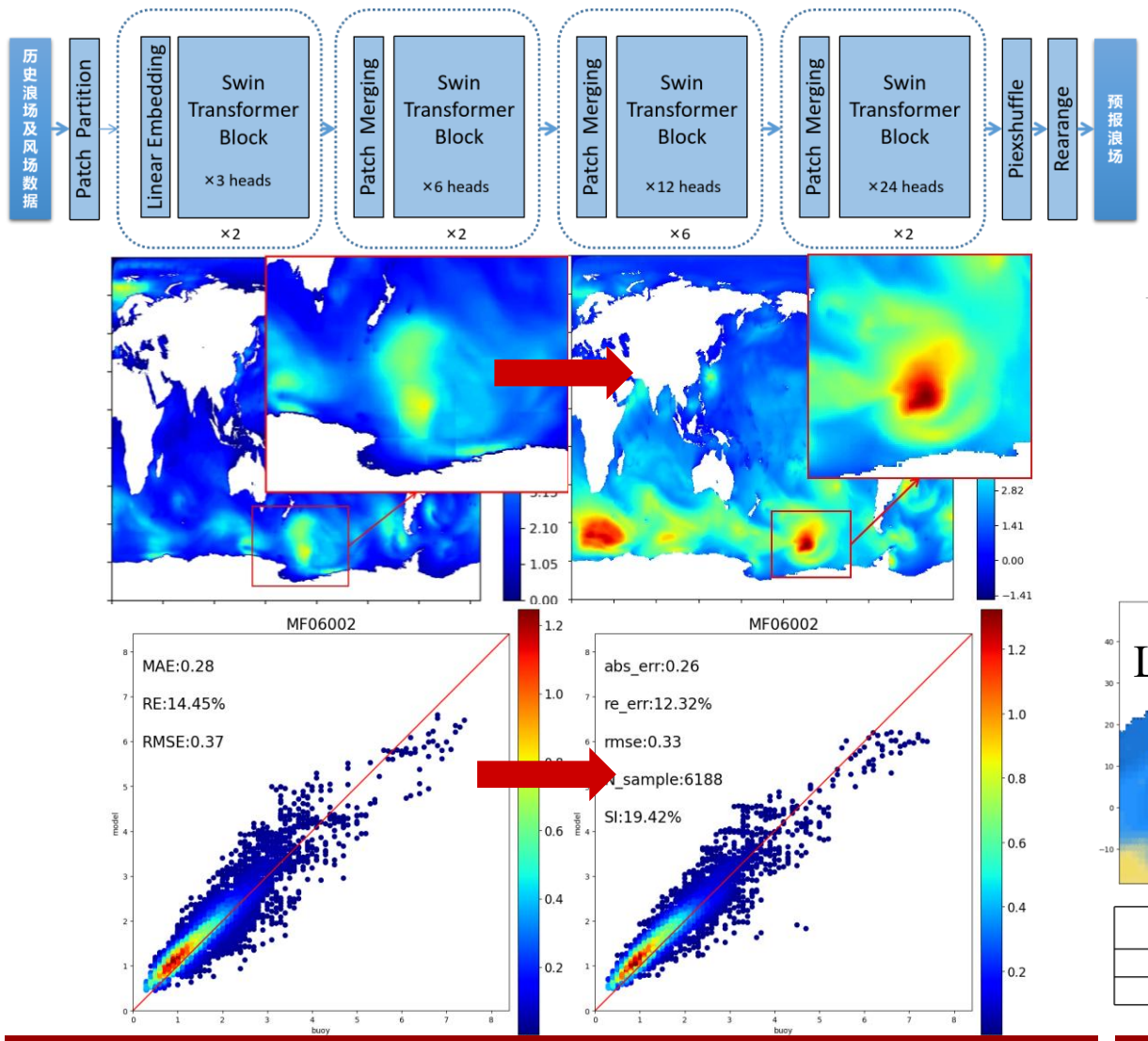
SFCN（State Force Coupled Network）

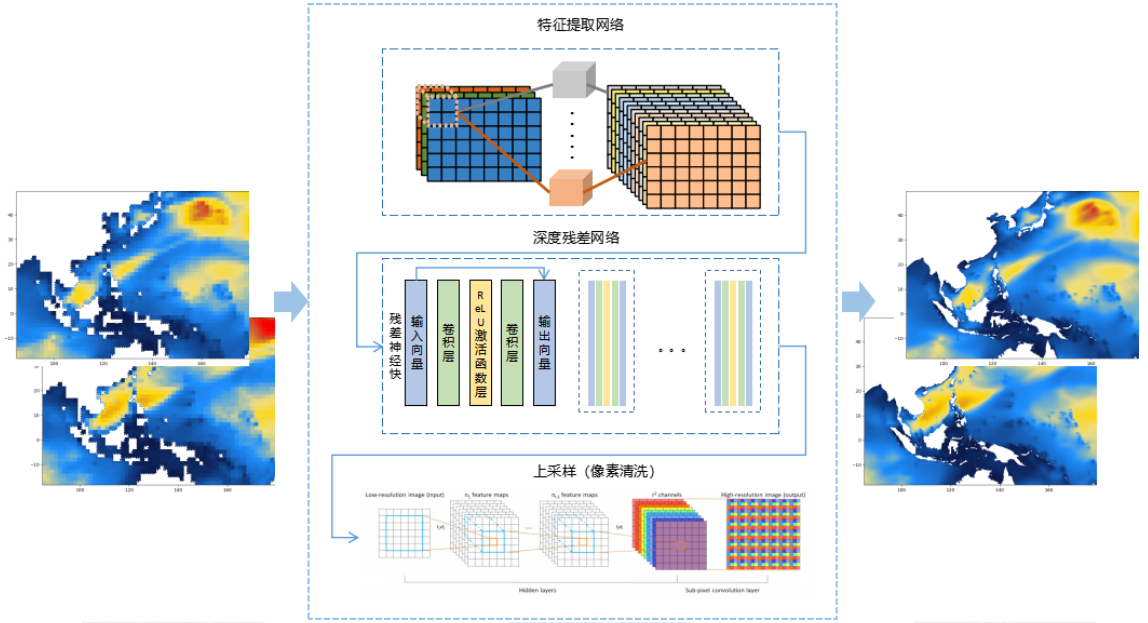


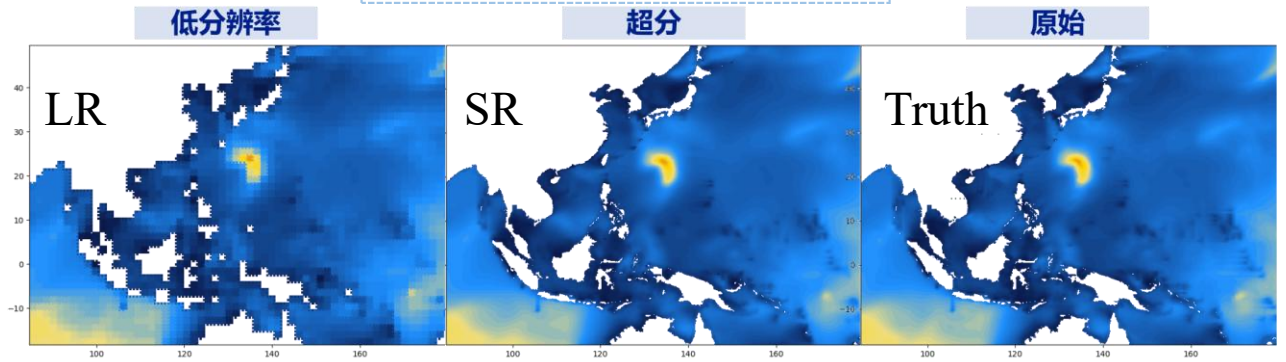
ODLF-Transformer（Observing Data Loss Function-Transformer）



2、Application & Verification







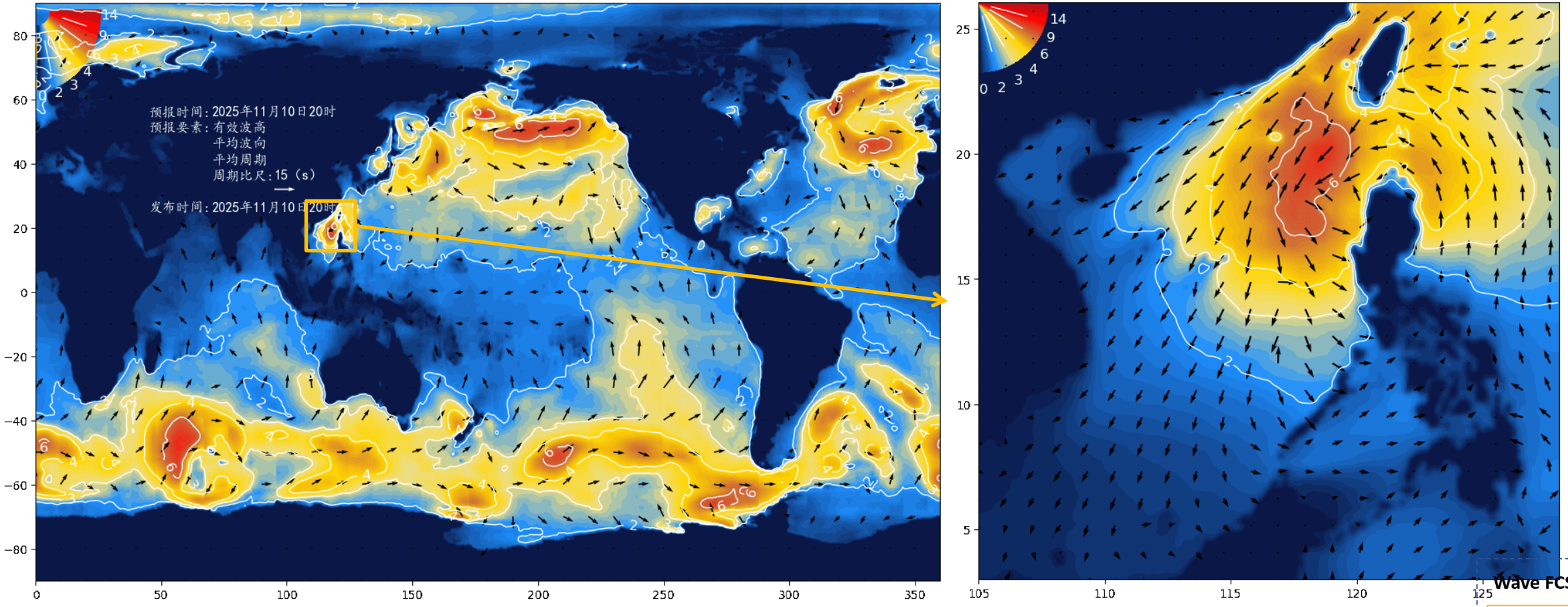
敏感试验	有数据增强，26分片	无数据增强，26分片	无数据增强，13分片	无数据增强，无分片
PSNR	42.875	44.3700	46.8581	47.2571
NIQE	16.8675	15.5082	13.8839	13.6314

Residual neural network and Pixel Shuffle build a smooth layer, enhancing adjacent feature correlation and removing forecast field unsmoothness.

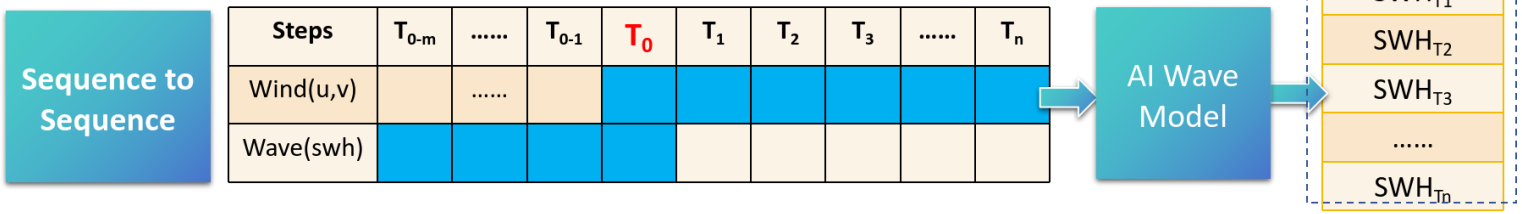
Super-resolution module developed for limited deployment bandwidth: 4× upsampling for low-res wind fields (file size reduced to 1/16), delivering high-precision wave forecasts.

3、Application & Verification

2025 Latest Typhoon Process (Operational System Results Typhoon Fung-wong)

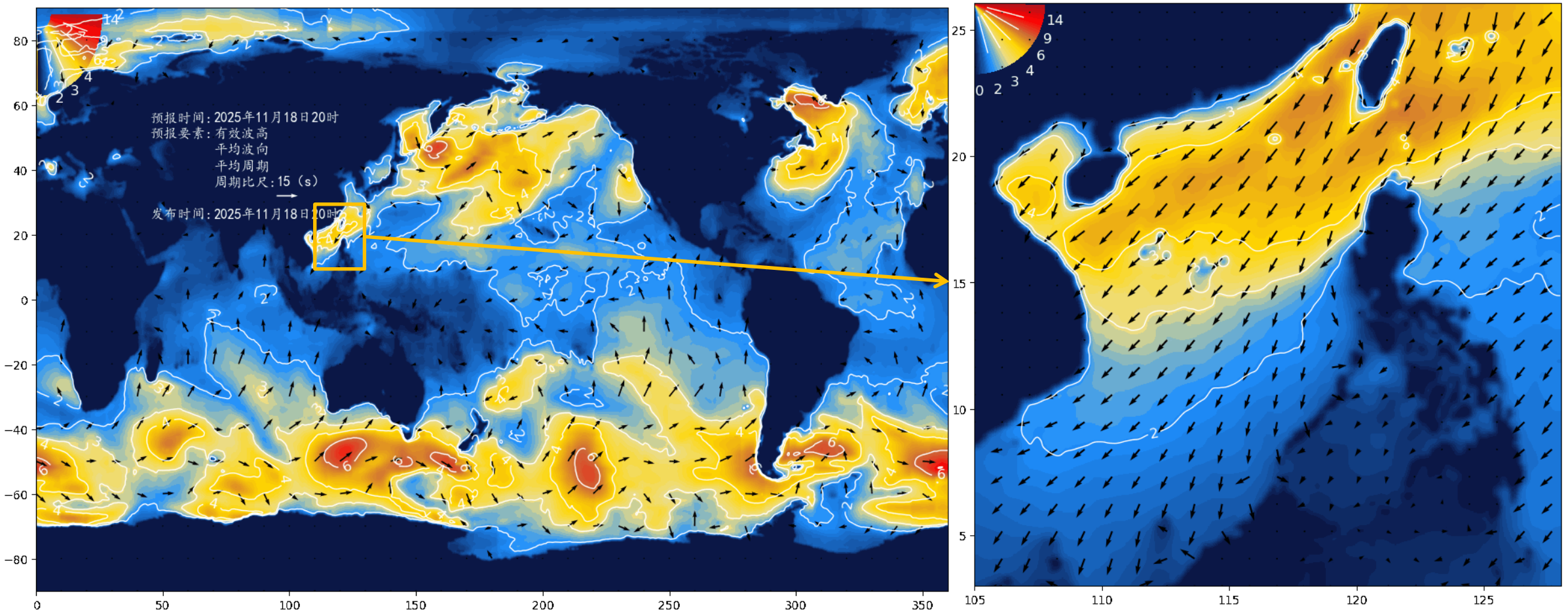


Global (~10 km) / South China Sea (~4 km), hourly | Forecast: Hs, mean wave period/direction

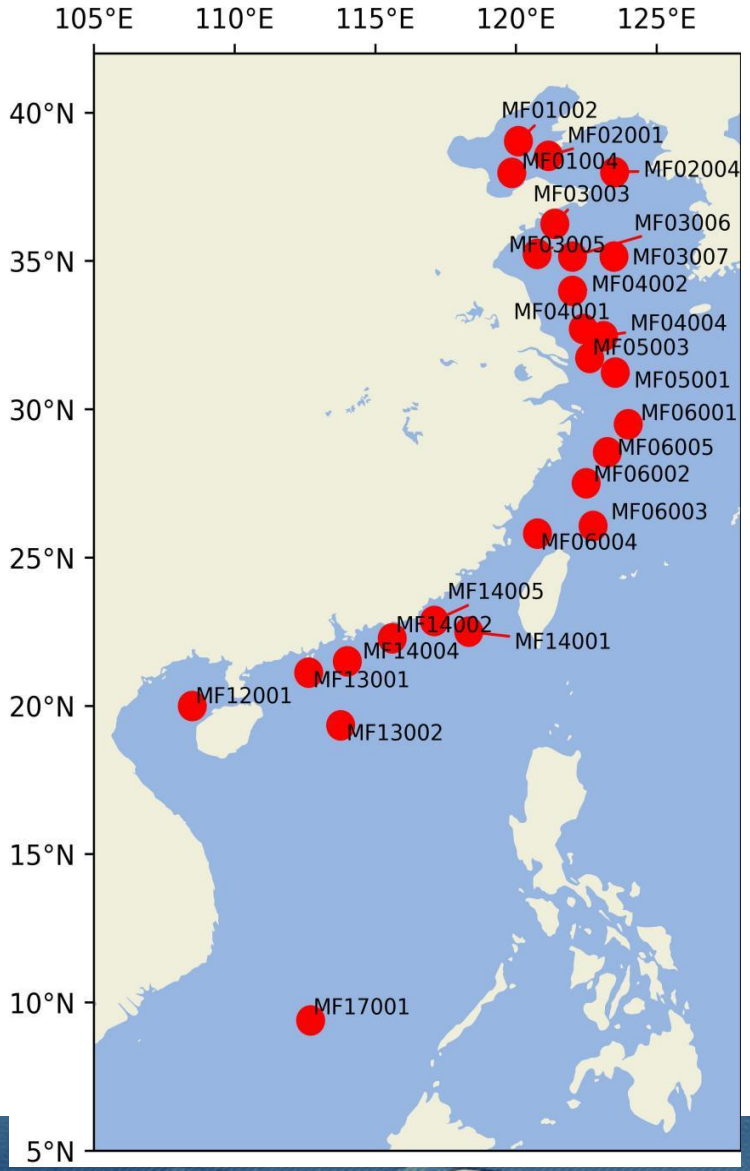


3、Application & Verification

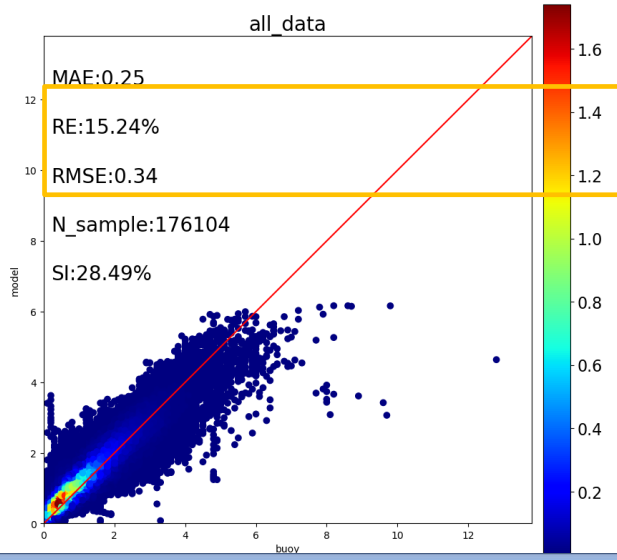
2025 Latest Cold Air Process (Operational System Results)



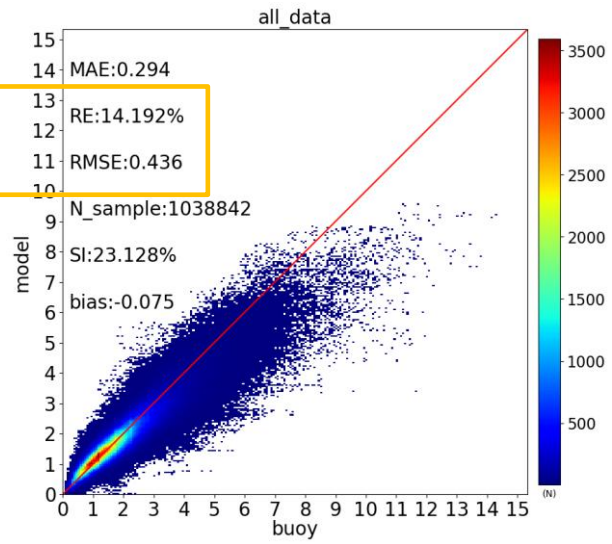
3、Application & Verification

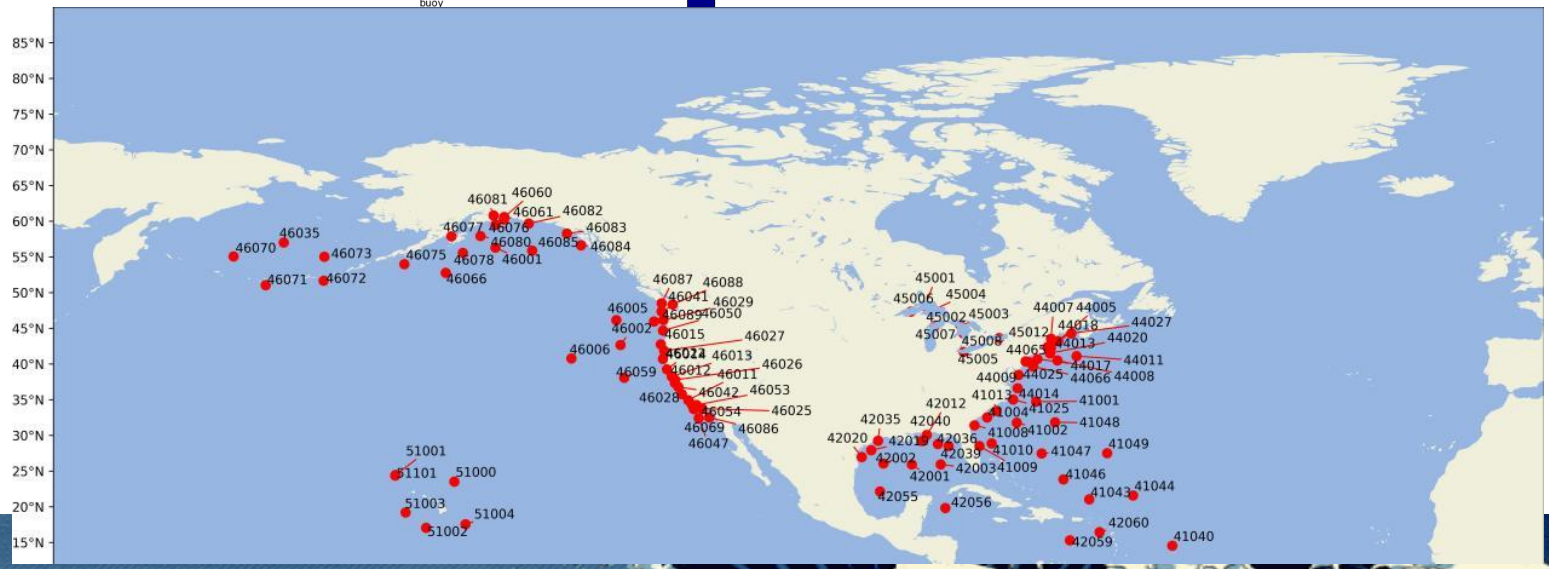


Chinese coastal buoys

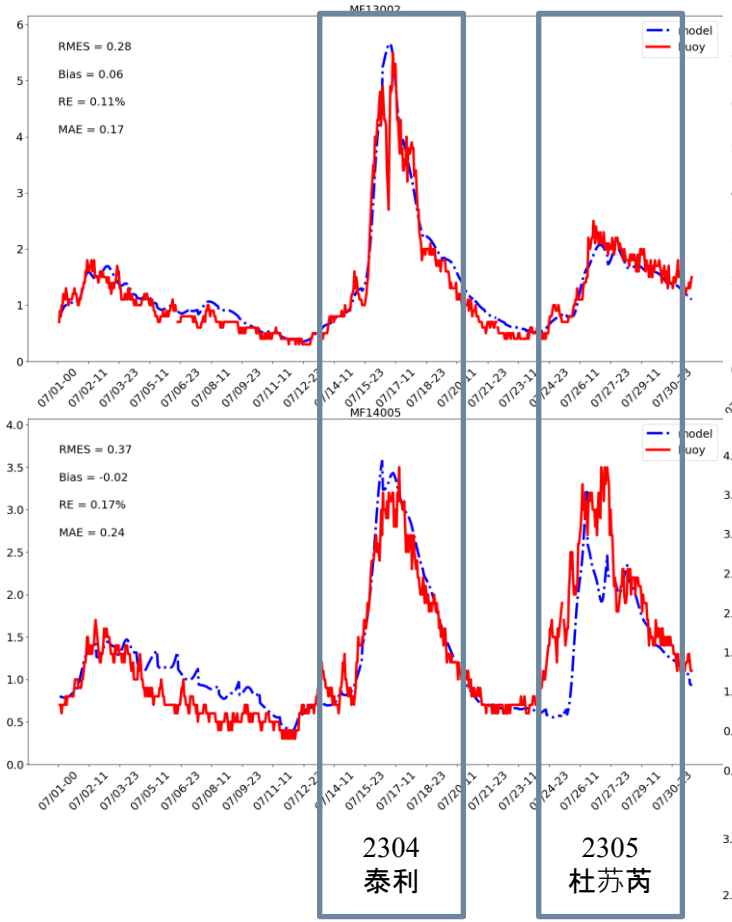


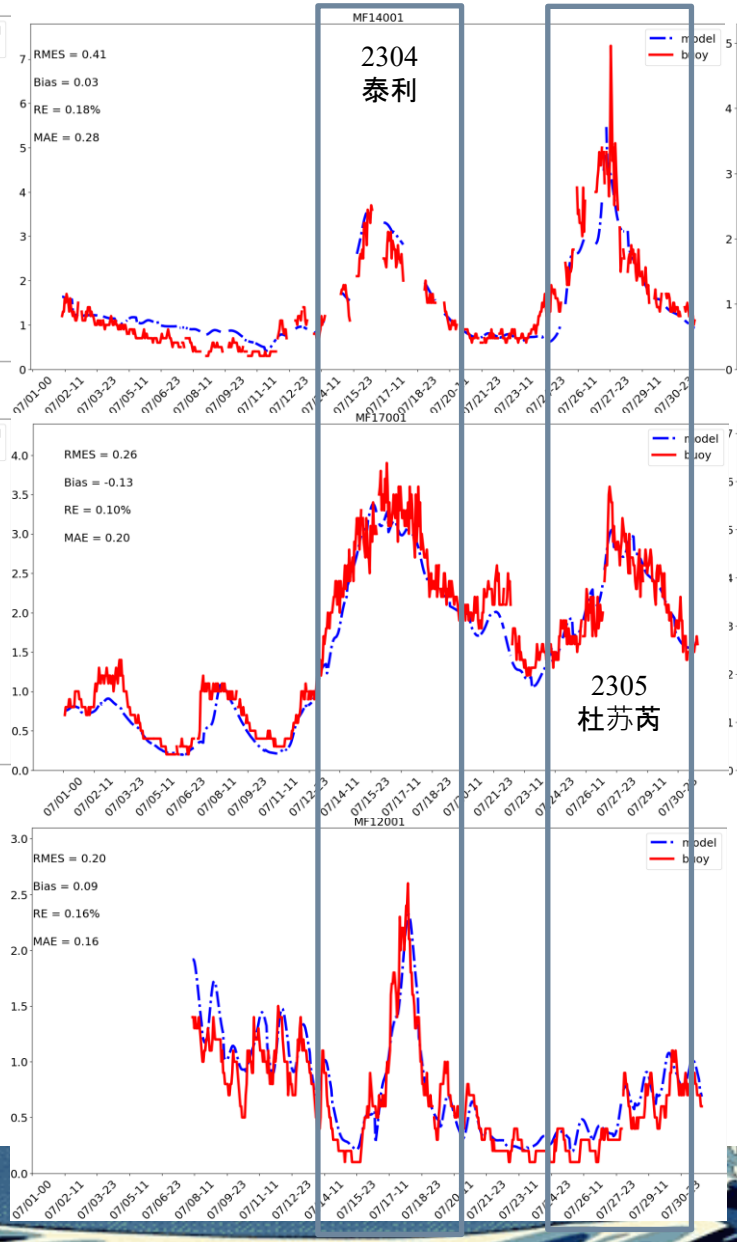
NDBC

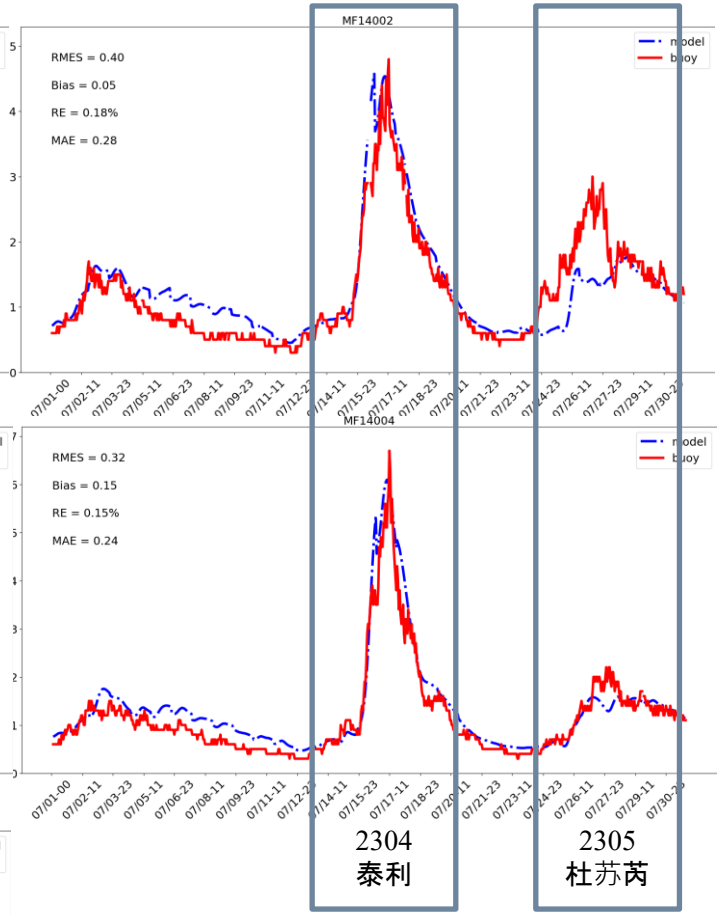




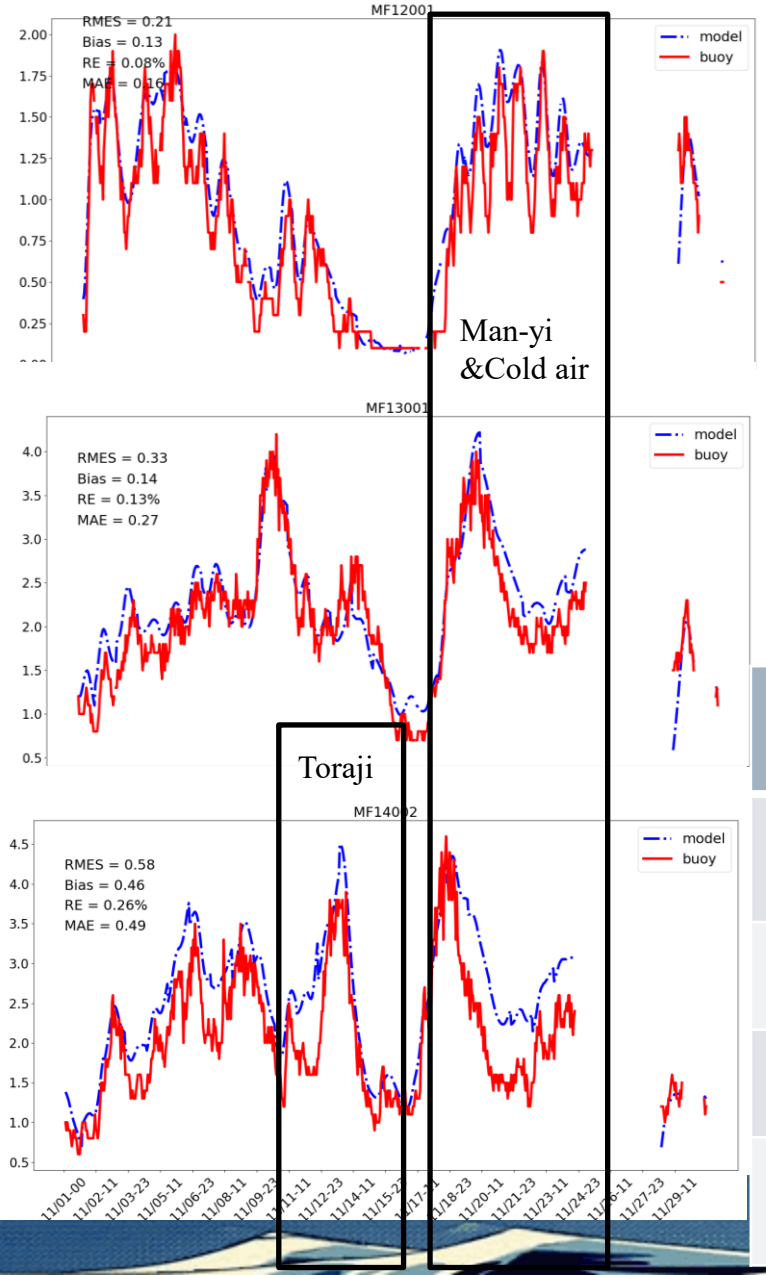
3、Application & Verification

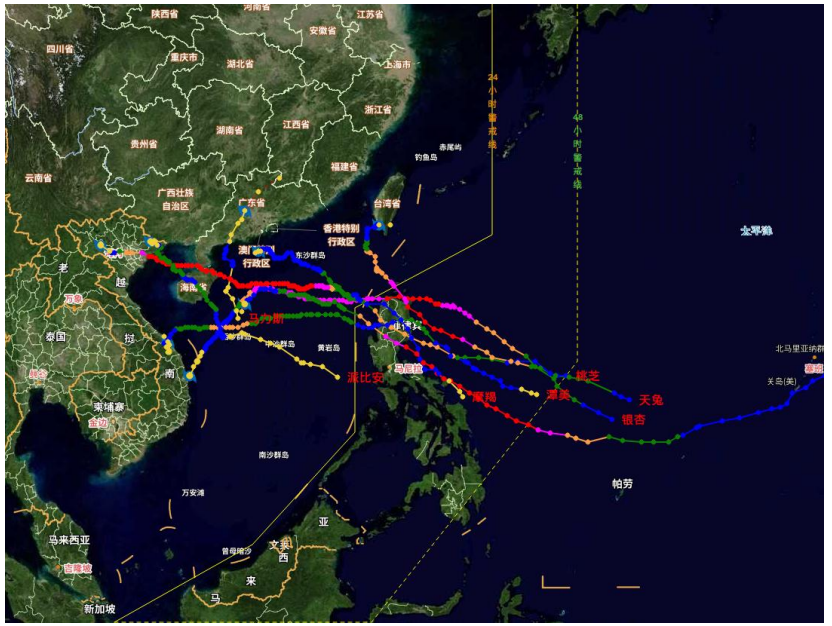




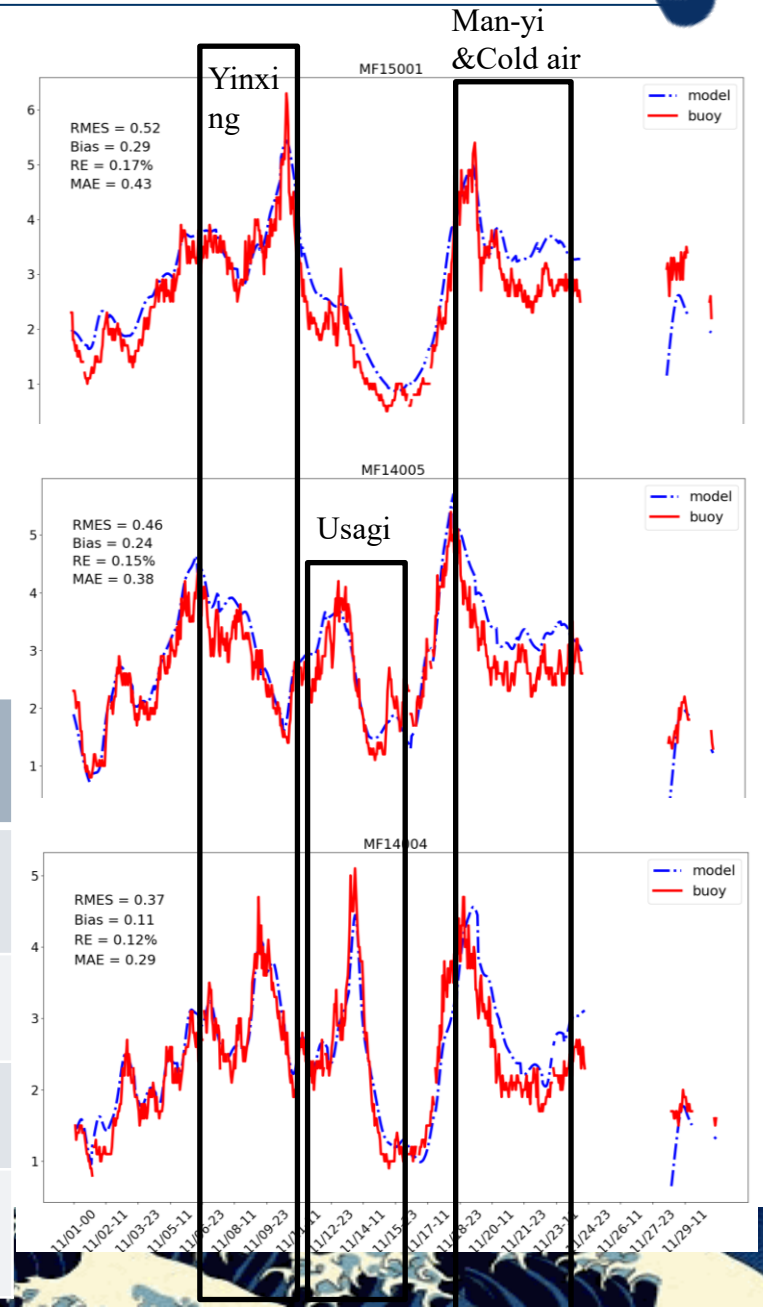


3、Application & Verification

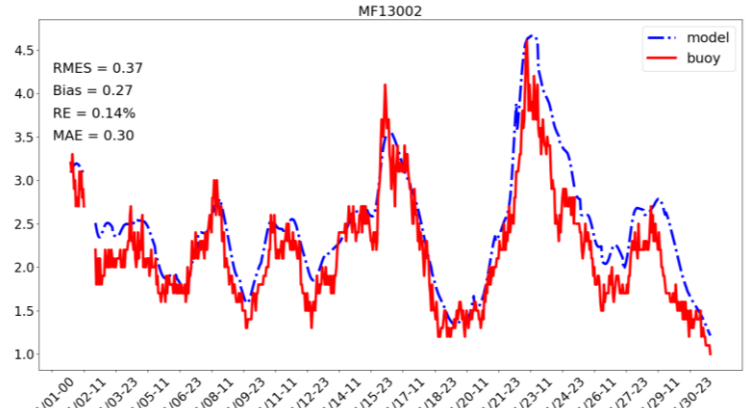


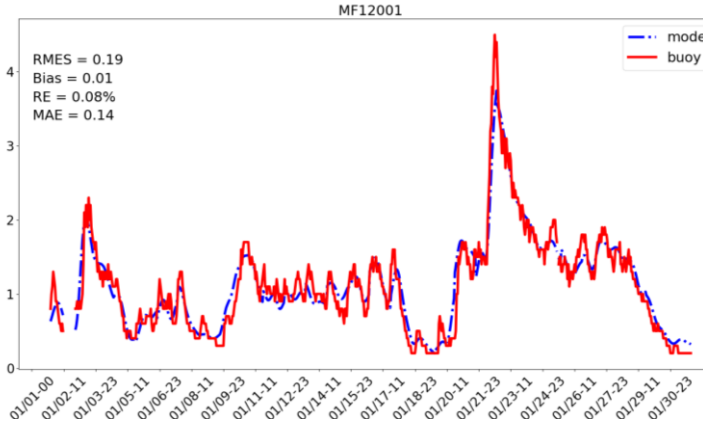


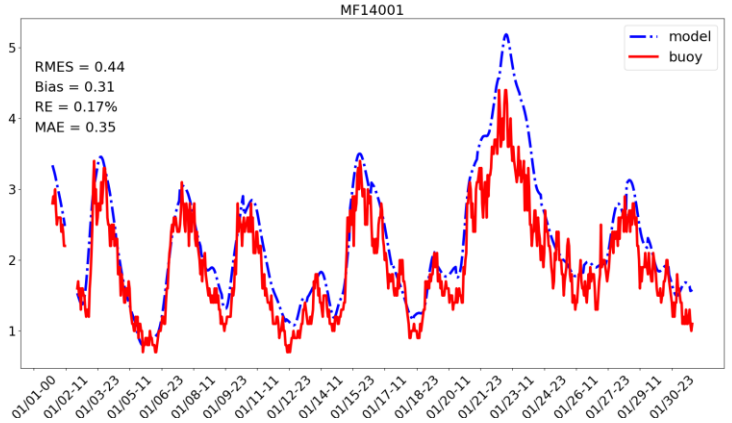
name	intensity	generation time	end time
Usagi	Super TY	11.12	11.16
Yinxing	STY	11.4	11.12
Toraji	TY	11.9	11.15
Man-yi	Super TY	11.9	11.19

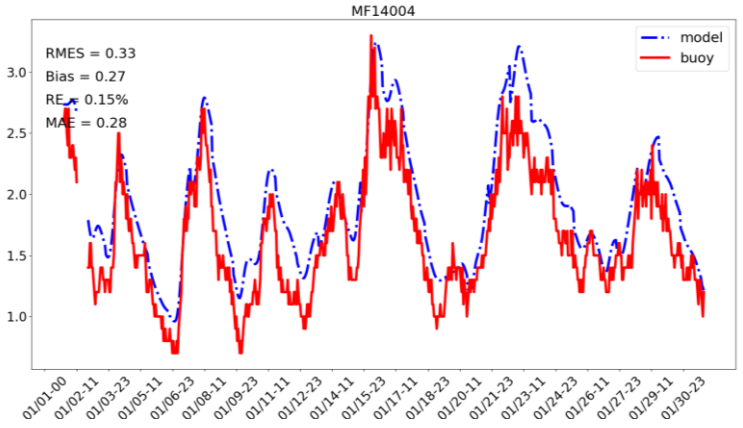


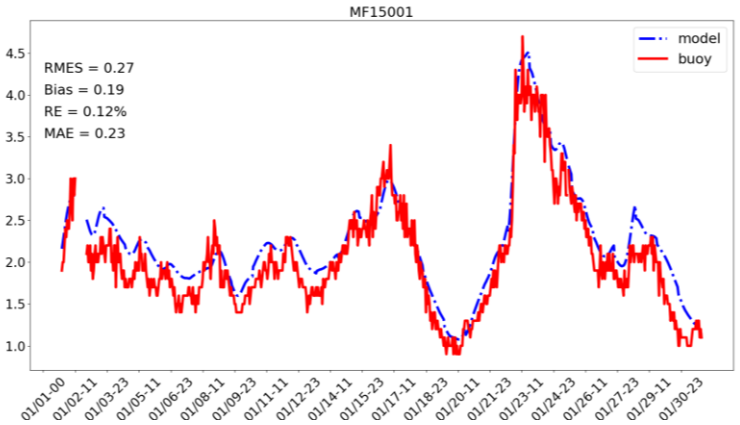
3、Application & Verification

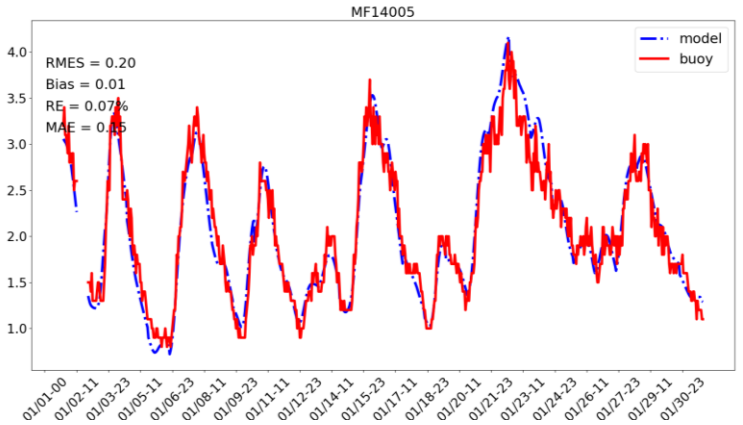




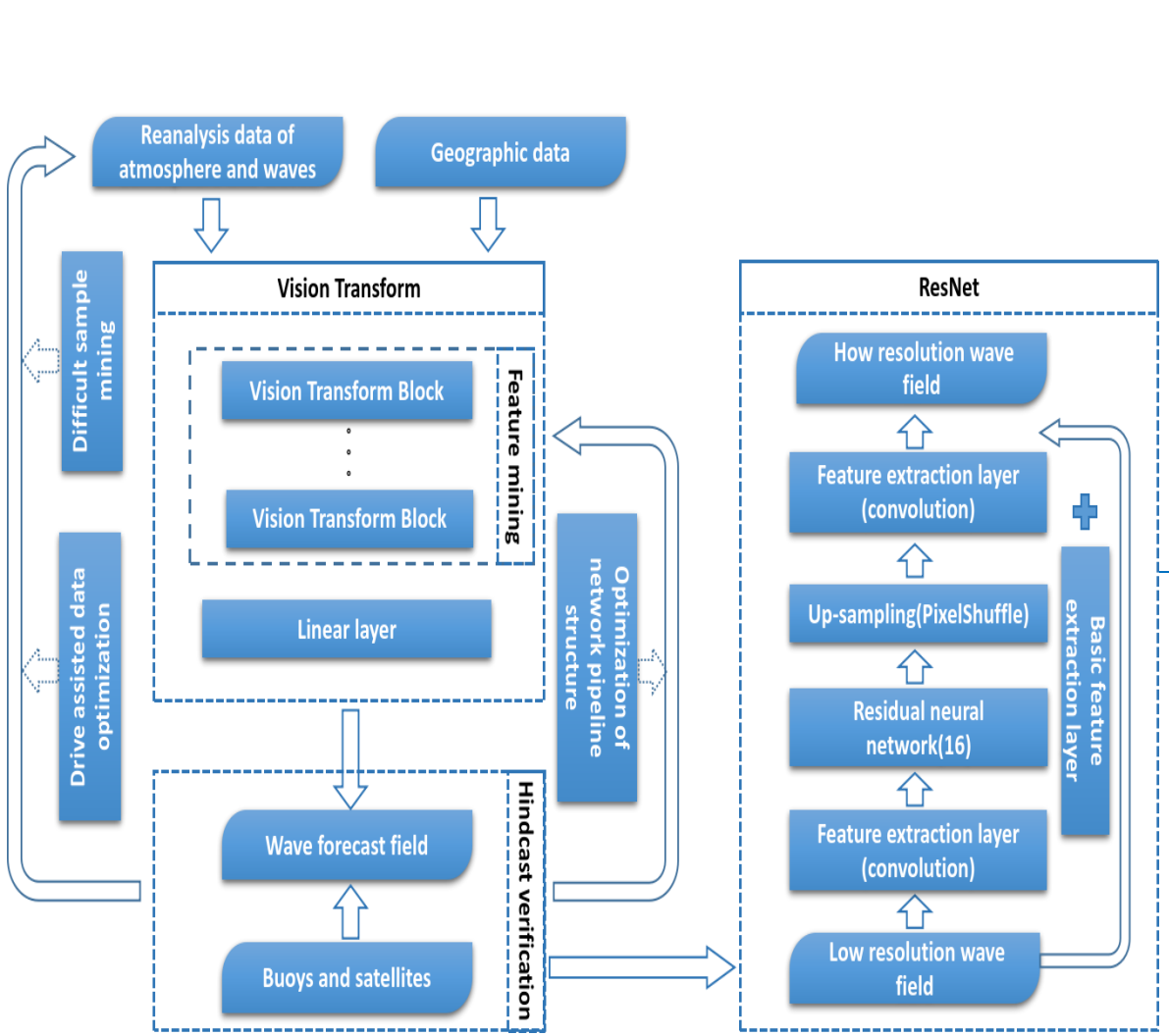


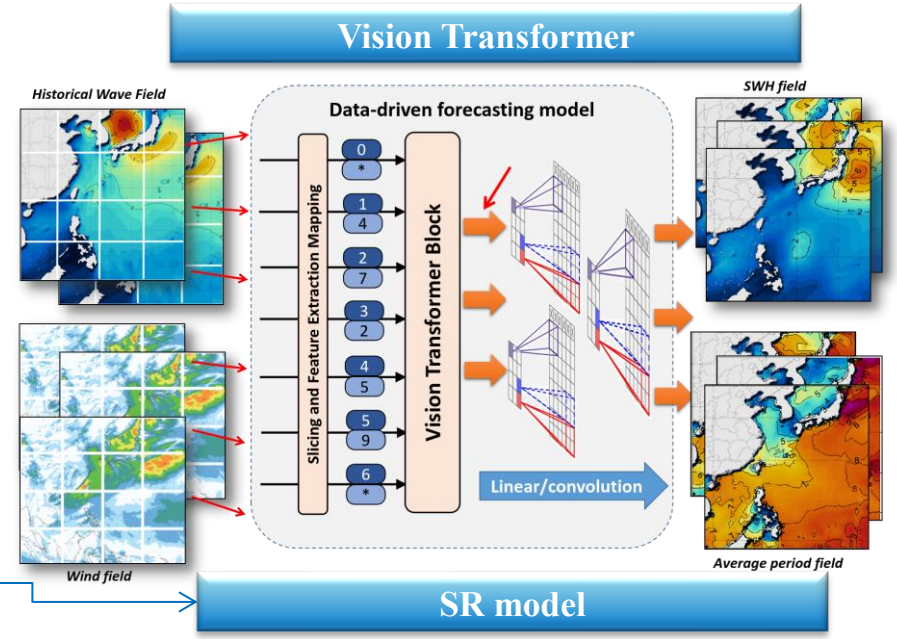


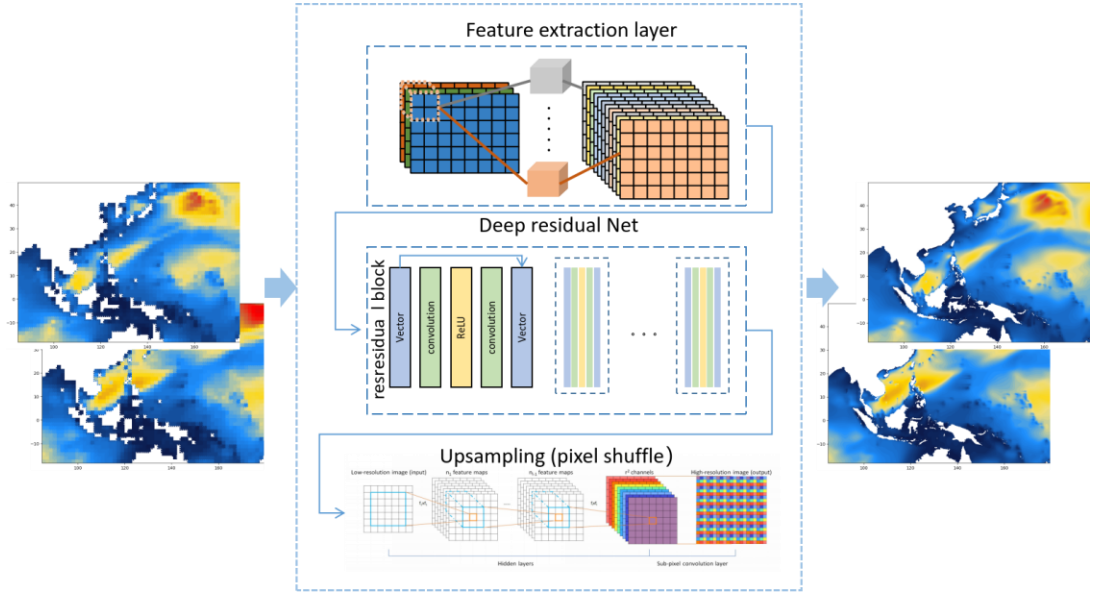




3、Application & Verification

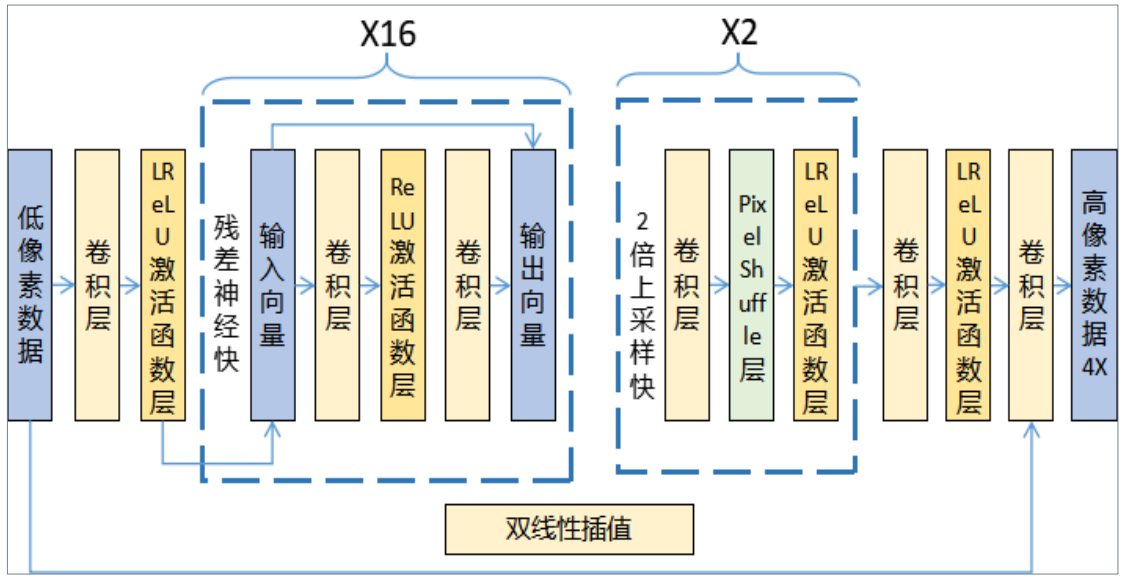




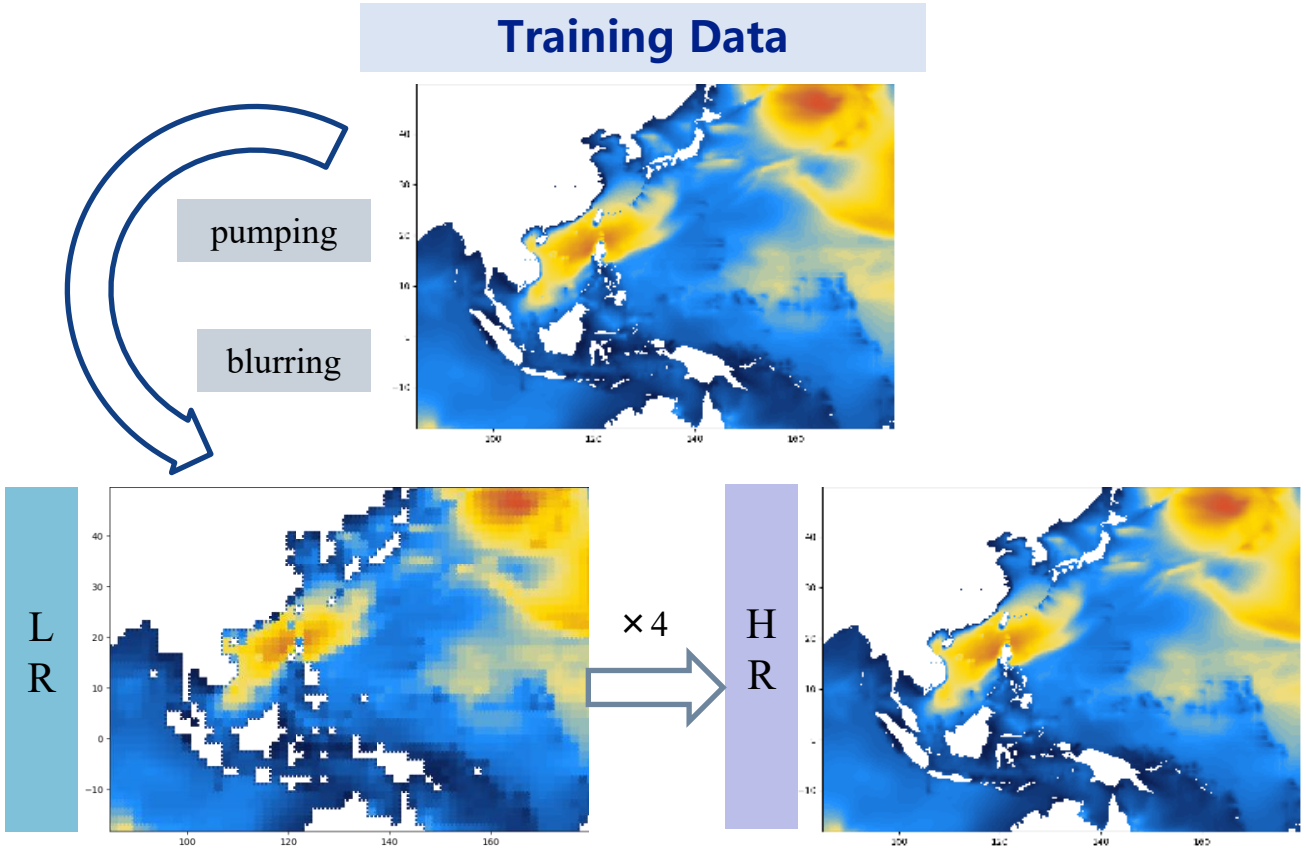


3、Application & Verification

SR Model Network Structure



Training Data



Training set: 2021, 0.1° NW Pacific, full-year significant wave height fields

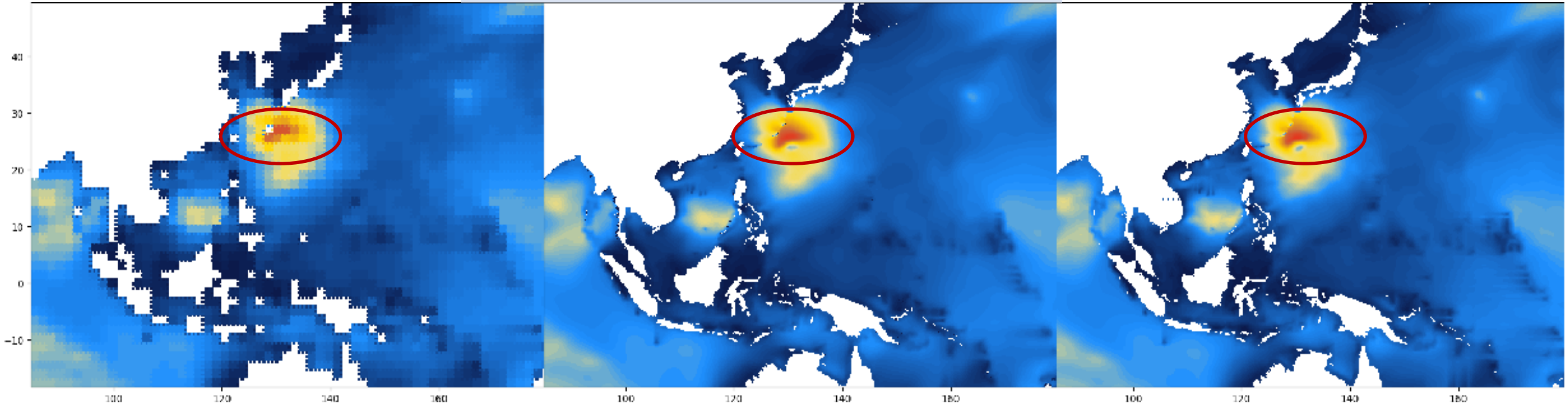
Validation set: 2022, same spatiotemporal scope, 10:1 temporal subsampling

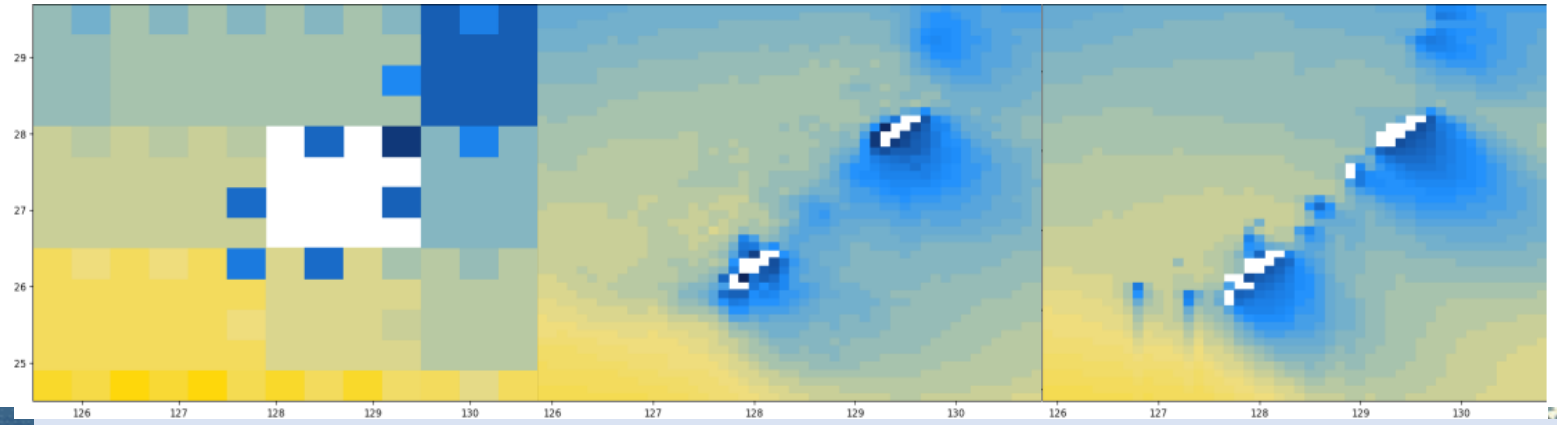
Test set: 2023 Feb–May, significant wave height fields

No terrain mask field in training inputs

3、Application & Verification

Typhoon Eye Structure Reproduction

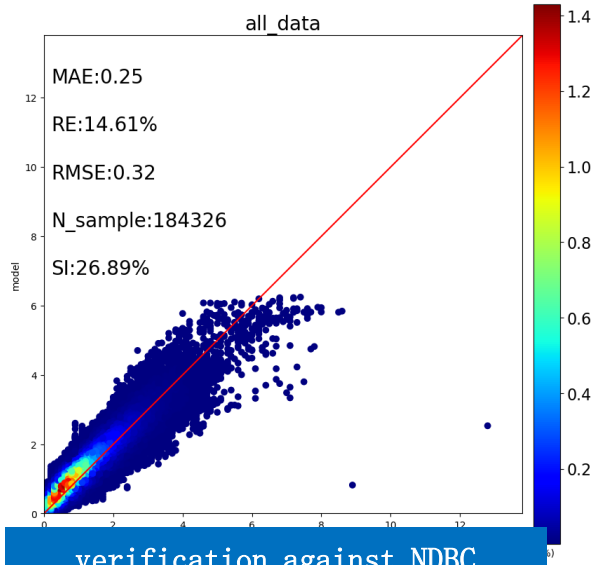




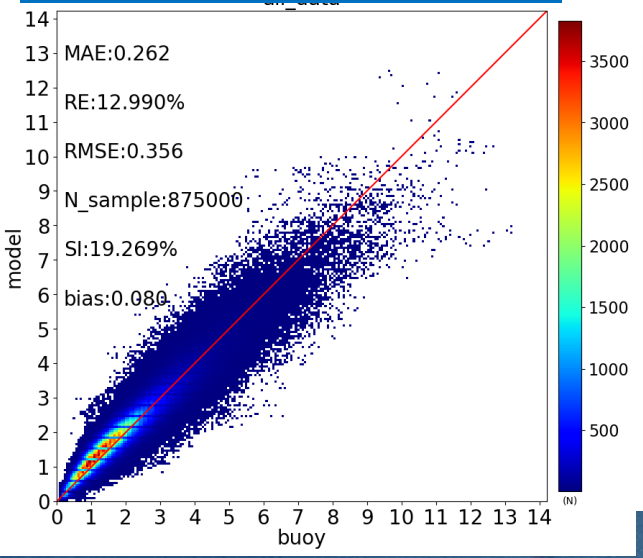
Reproduction of the shielding effect of islands on ocean waves

3、Application & Verification

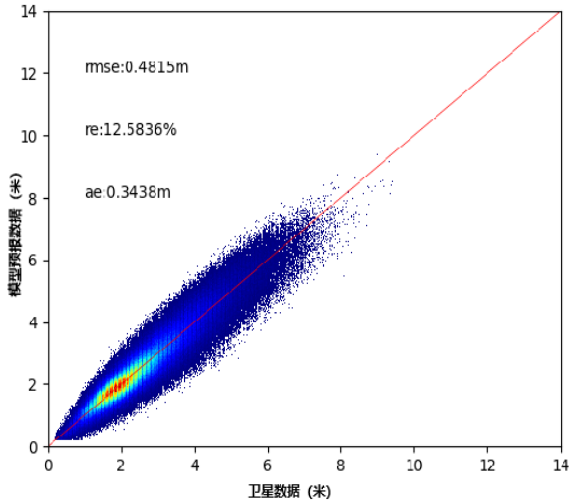
Coastal Buoy Verification(China)



verification against NDBC

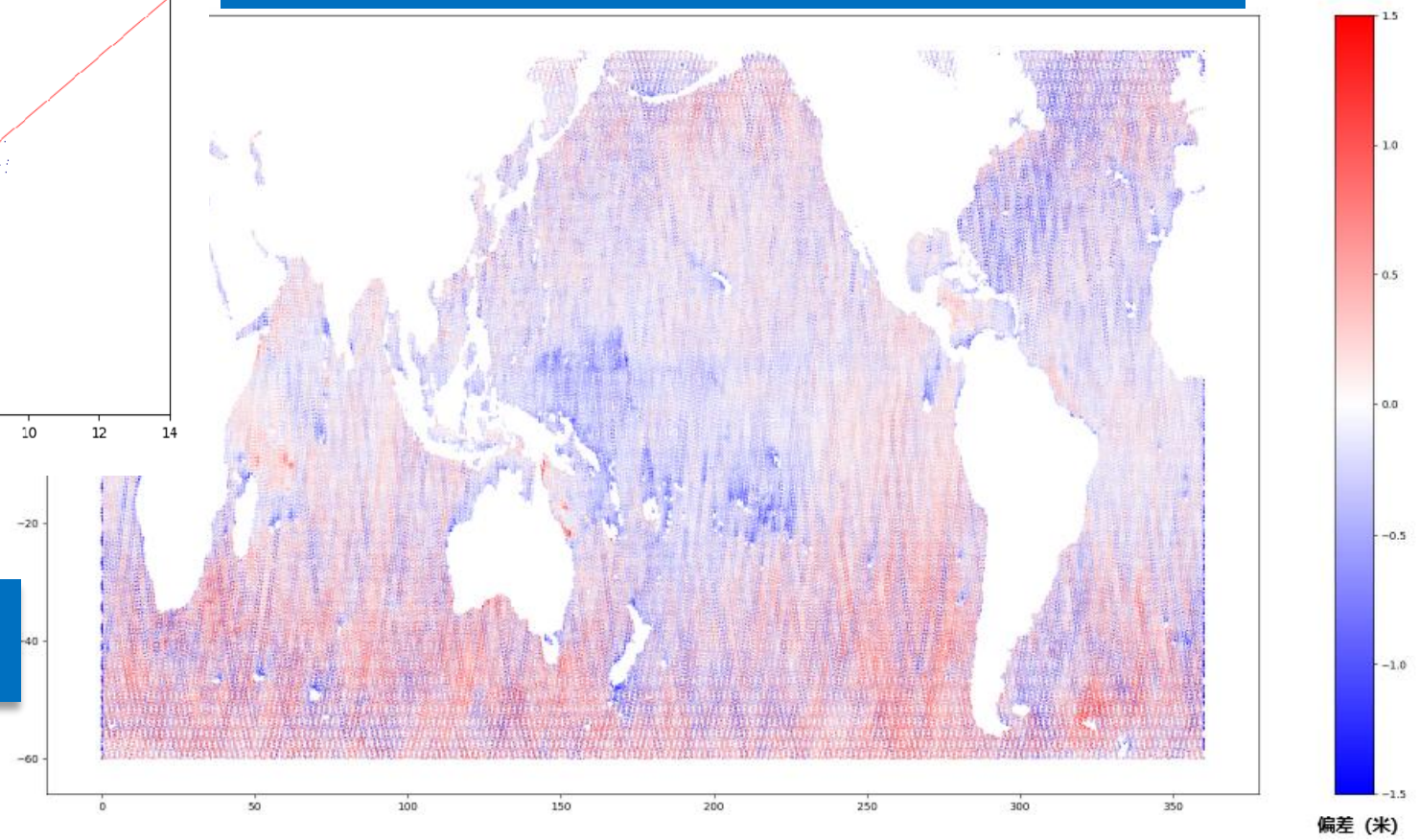


CFOSAT altimeter



Driving wind field (0.4°)

Bias distribution against CFOSAT altimeter



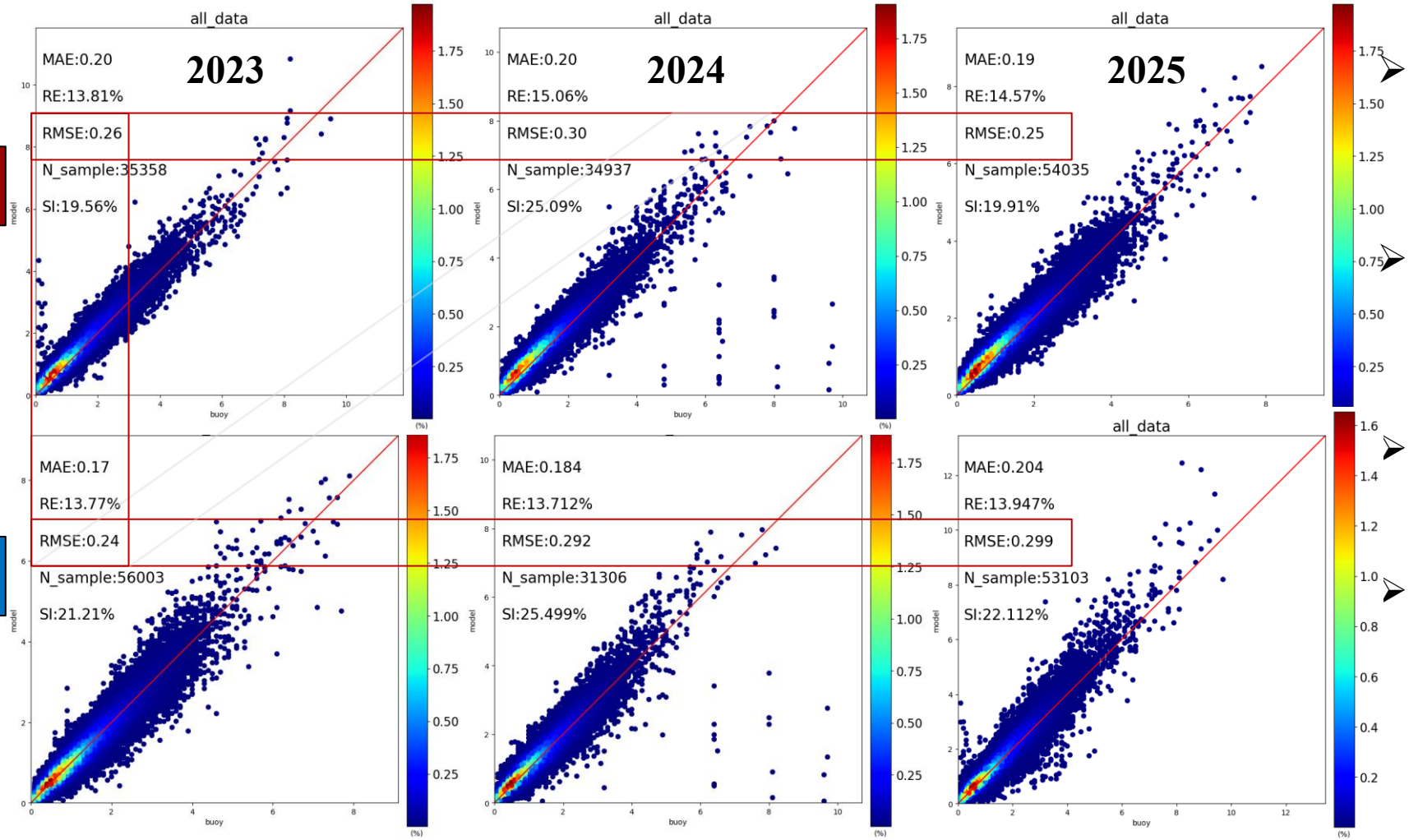
- Verification results outperform the pure attention mechanism model
- Verification results are slightly inferior to numerical forecast outputs

4、Next Work

Current issues： Consistency of Wave Model and Forcing Wind Field

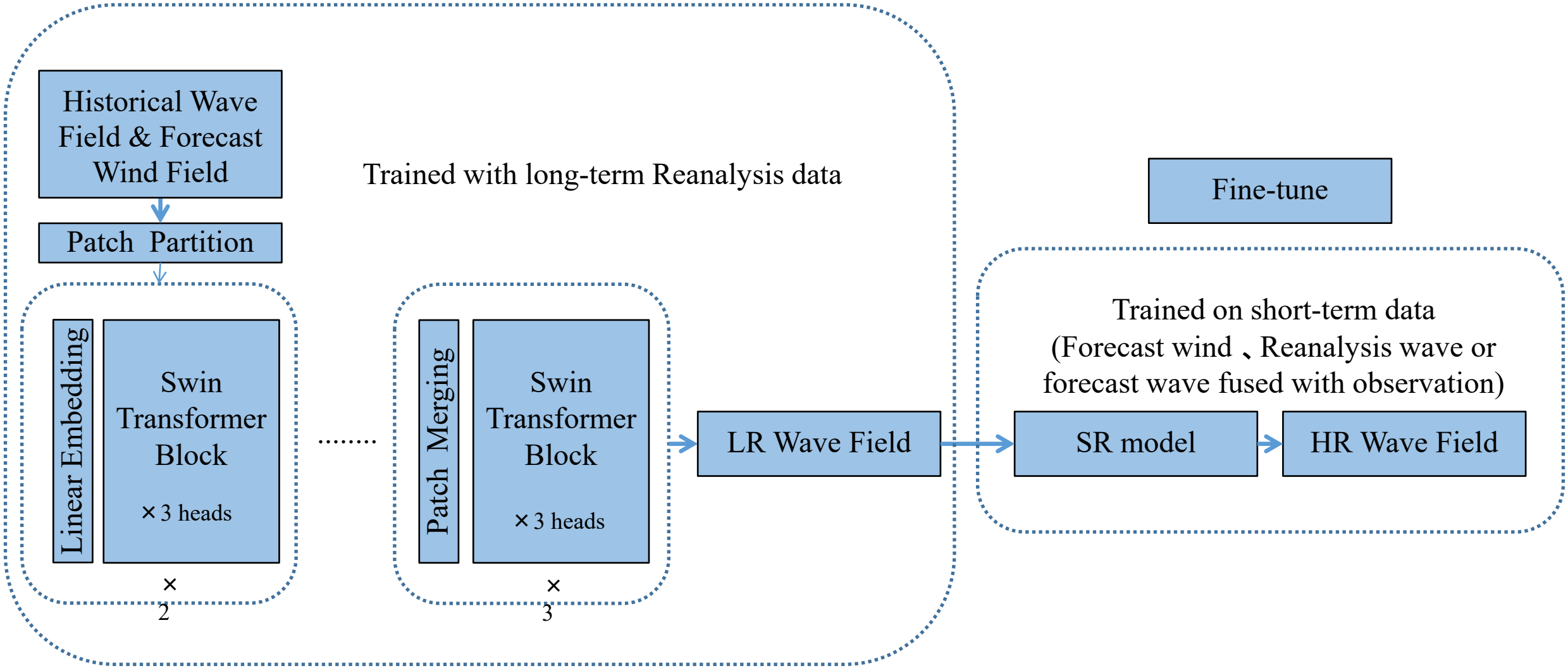
ECMWF

NMEFC

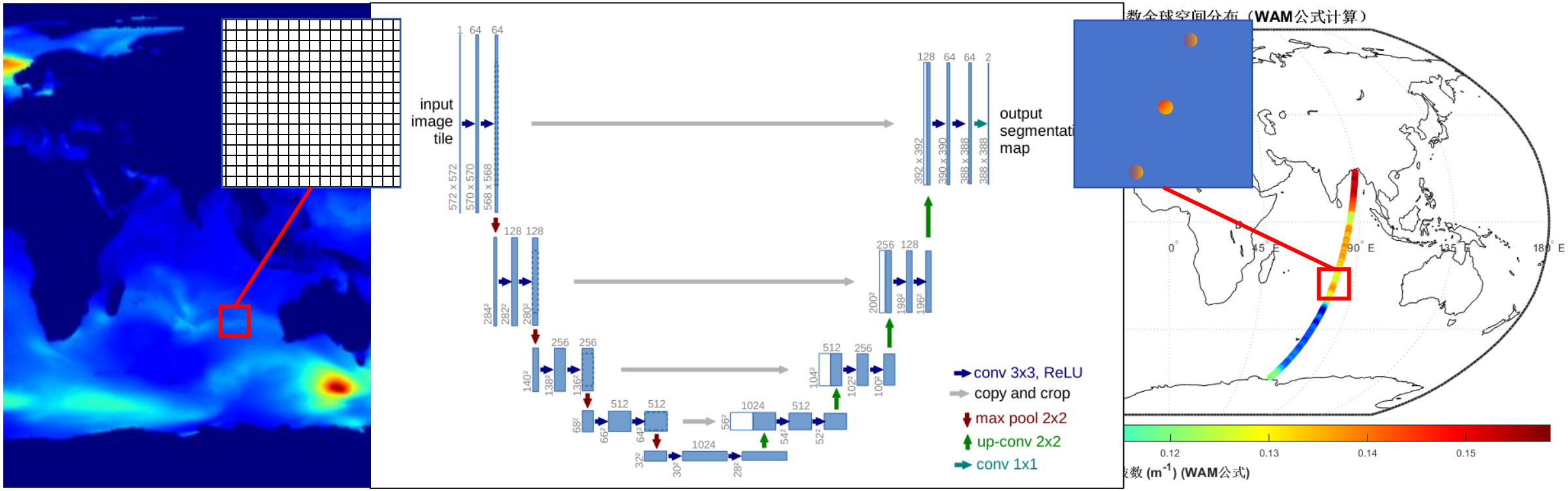


- 2023: Our center's verification metrics > ECMWF
- 2023–2025: Our center's metrics, slight year-on-year decline
- 2025: Our center's RMSE < ECMWF
- ECMWF wave field: Fluctuating, 2024 = relatively poor performance

4、Next Work

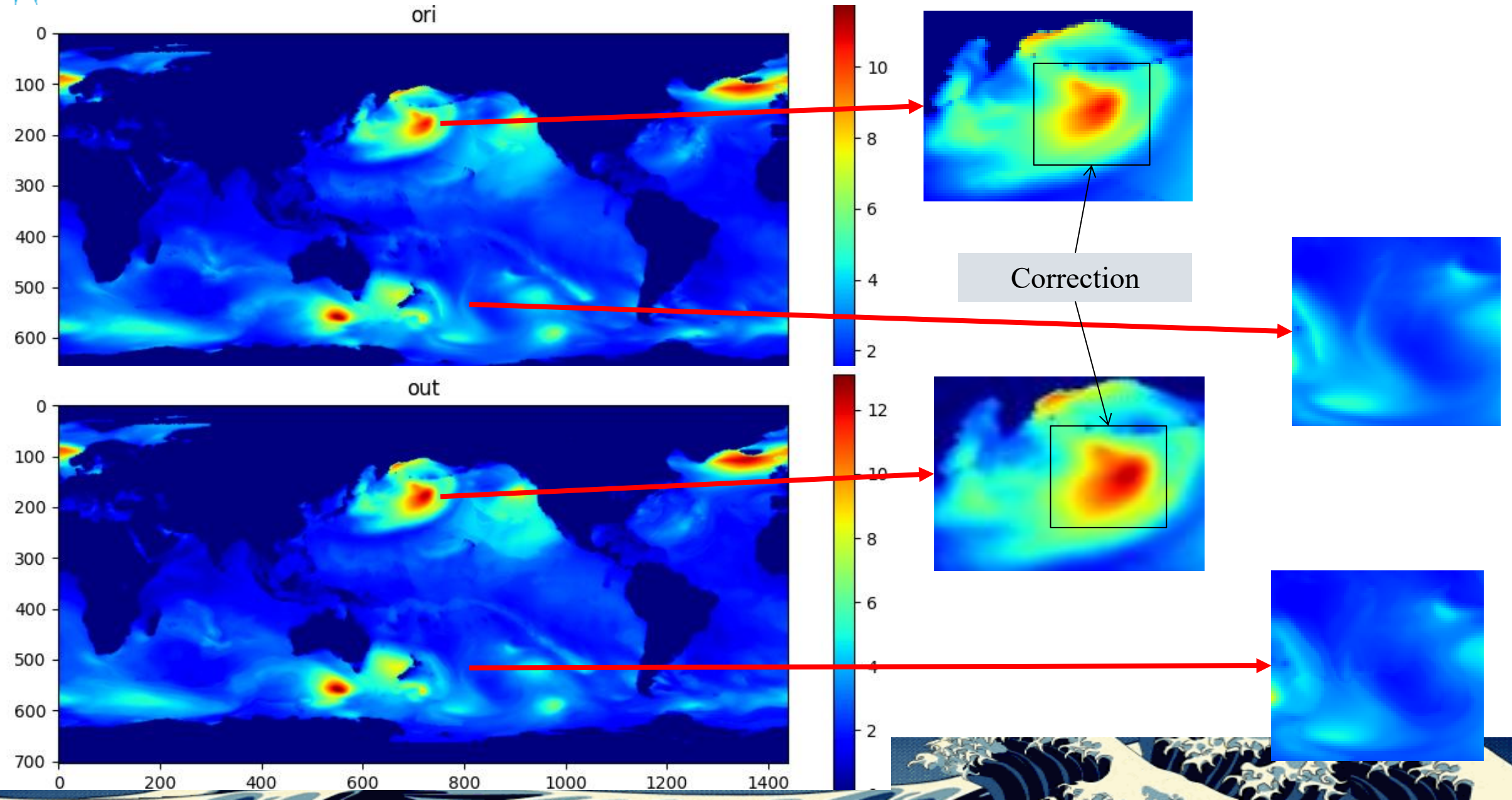

Historical Wave Field & Forecast Wind Field
Patch Partition
Linear Embedding
Swin Transformer Block
× 3 heads
×
2
.....
Patch Merging
Swin Transformer Block
× 3 heads
×
3
Trained with long-term Reanalysis data
LR Wave Field
Fine-tune
Trained on short-term data
(Forecast wind 、Reanalysis wave or forecast wave fused with observation)
SR model
HR Wave Field

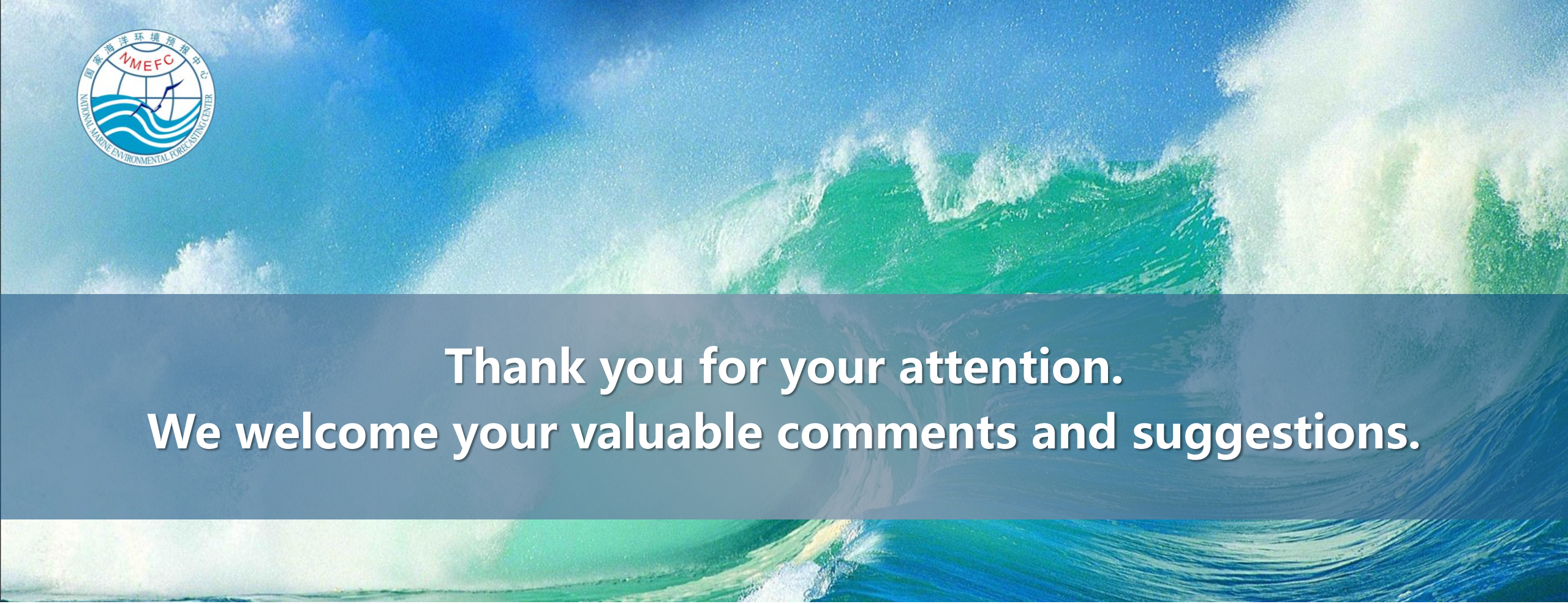
4、Next Work



$$LOSS = F^{OnTrack}(SWH^I, SWH^N), with\ mask$$

4、Next Work





Thank you for your attention.
We welcome your valuable comments and suggestions.

- China Marine Forecast Network: http://www.oceanguide.org.cn/hyyj/
- Official Website of National Marine Environmental Forecasting Center (NMEFC): http://www.nmefc.cn
- WeChat Official Accounts: National Marine Forecast Station, National Marine Environmental Forecasting Center

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