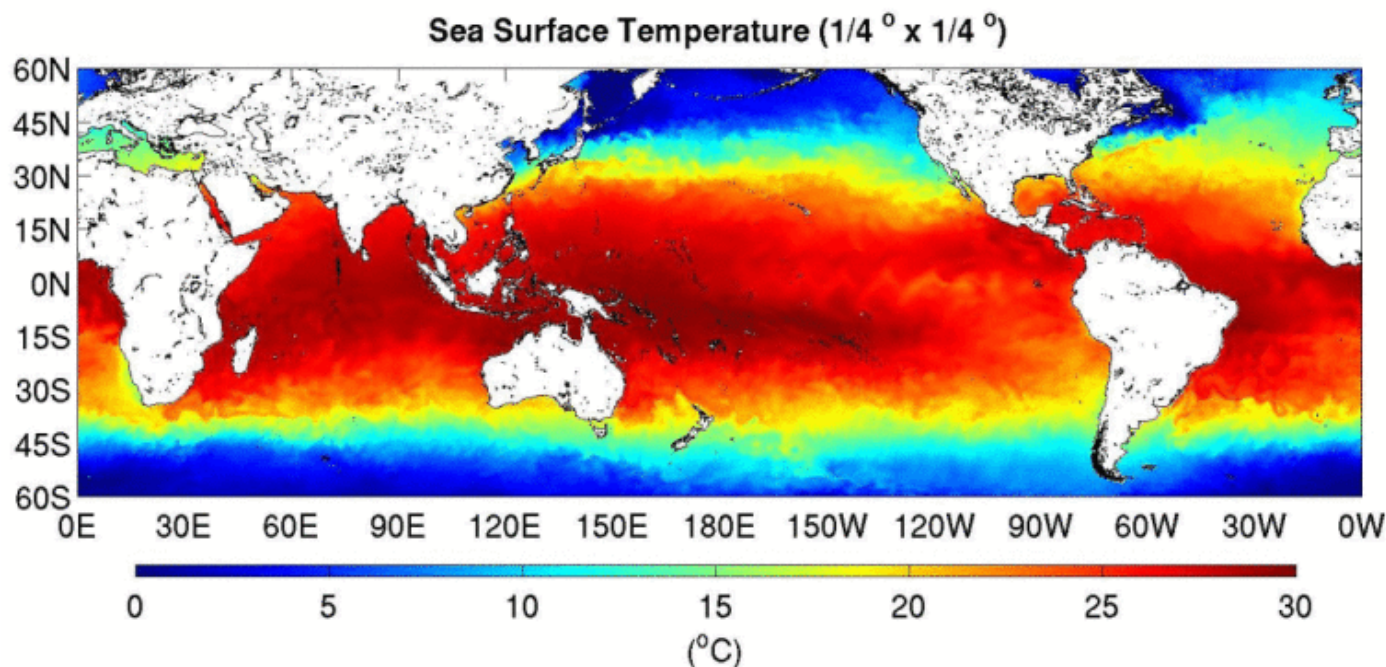


# Multi-scale Ocean-atmosphere Coupled Modelling System

Day 000



Yu-Heng Tseng<sup>1,2</sup>, Yun-Chuan Shao<sup>1,2</sup>, Shi-Shian Tseng<sup>2,3</sup>, Chung-Wei Lee<sup>2,3</sup>, Jen-Ho Chen<sup>3</sup>

<sup>1</sup>*Institute of Oceanography, National Taiwan University, Taiwan*

<sup>2</sup>*Ocean Center, National Taiwan University, Taiwan*

<sup>3</sup>*Central Weather Administration, Taiwan*



## Education

1991-1995 (B.S.)	National Taiwan University, Mechanical Engineering
1997-1999 (M.S.)	Stanford University, Department of Mechanical Engineering
1999-2003 (Ph.D)	Stanford University, Department of Civil and Environmental Engineering.

## Professional Experiences

2003-2004	Johns Hopkins University, Mechanical Engineering
2004-2006	Lawrence Berkeley National Laboratory, Computational Research Division
2006-2012	National Taiwan University, Department of Atmospheric Sciences
2012-2017	National Center for Atmospheric Research, Climate and Global Dynamics Laboratory
2017-	National Taiwan University, Institute of Oceanography
2021-	National Taiwan University, Ocean Center (Director)

Research interesting: turbulence and mixing, Computational Fluid Dynamics, high-order numerical method, non-hydrostatic model, regional and global ocean circulation model, air-sea (ocean-atmosphere) interaction, climate model development and parameterization

### 3. 重大農業災害產物估計損失 (83-107年)

#### Estimated Production Loss of Major Agricultural Disasters (1994-2018)

單位：千元 Unit: N.T.\$1,000

災 害 別	農林漁牧業產物損失					Disaster
	Products loss					
	合計	農作物	畜產	漁產	林產	
	Total	Crop	Livestock	Fishery	Forestry	
<b>颱風</b>						<b>Typhoon</b>
98年8月莫拉克颱風	19 081 502	10 109 283	1 551 051	4 314 333	3 106 835	Aug. Morakot,2009
85年8月賀伯颱風	18 543 463	14 779 276	467 235	2 430 296	866 656	Aug. Herb,1996
105年梅姬颱風及9月風災雨害	18 411 548	16 929 138	57 936	105 192	1 319 283	Sep. Megi & Flood,2016
104年8月蘇迪勒颱風	9 981 659	9 673 773	21 695	229 633	56 558	Aug. Soudelor,2015
96年10月柯羅莎颱風	7 642 586	7 576 684	7 974	42 141	15 787	Oct. Korsa,2007
94年7月海棠颱風	7 592 991	6 678 433	74 110	634 321	206 127	July Haitang,2005
99年9月凡那比颱風	7 529 266	6 544 674	181 010	768 954	34 628	Sep. Fanapi,2010
87年10月瑞伯颱風	6 669 671	6 168 219	25 445	451 635	24 372	Oct. Zeb,1998
97年9月蕃薯颱風	6 421 790	6 328 303	8 266	81 886	3 335	Sep. Jangmi,2008
89年8月碧利斯颱風	6 119 063	5 719 063	76 783	140 381	182 836	Aug. Bilis,2000
<b>暴雨</b>						<b>Flood</b>
94年6月暴雨	4 846 084	3 648 782	219 416	962 763	15 123	June Chanchu,2005
107年0823熱帶低壓水災	3 453 766	2 765 547	176 562	510 714	943	Aug. 23 Flood,2018
100年11月暴雨	2 368 718	2 368 718	-	-	-	Nov. Flood,2011
102年4月霪雨	2 305 494	2 305 494	-	-	-	Apr. Flood,2013
95年5月暴雨(0609水災)	2 231 320	2 204 480	20 261	4 850	1 729	May Flood,2006
106年0601暴雨	2 209 991	2 193 939	8 114	5 641	2 297	June 01 Flood,2017
87年6月暴雨	1 913 308	1 883 263	-	28 100	1 945	June Flood,1998
<b>地震</b>						<b>Earthquake</b>
88年921集集大地震	2 061 854	1 288 243	478 263	12 070	283 278	921Earthquake,1999
<b>寒害</b>						<b>Frost Damage</b>
105年1月寒流	10 840 267	4 207 867	897	6 631 498	6	Jan. Cold Surge,2016
88年12月寒害	3 143 387	1 930 372	-	1 213 015	-	Dec. Frost Damage,1999
94年1-3月低溫	2 817 382	2 670 357	-	147 025	-	Jan. Frost Damage,2005
<b>冰雹</b>						<b>Hailstone</b>
87年2月冰雹	3 082 910	3 082 910	-	-	-	Feb. Hailstone,1998
91年12月冰雹	498 215	498 215	-	-	-	Dec. Hailstone,2002
<b>乾旱</b>						<b>Drought</b>
85年7月乾旱	452 313	452 313	-	-	-	July Drought,1996
91年4月乾旱	341 291	341 291	-	-	-	Apr. Drought,2002

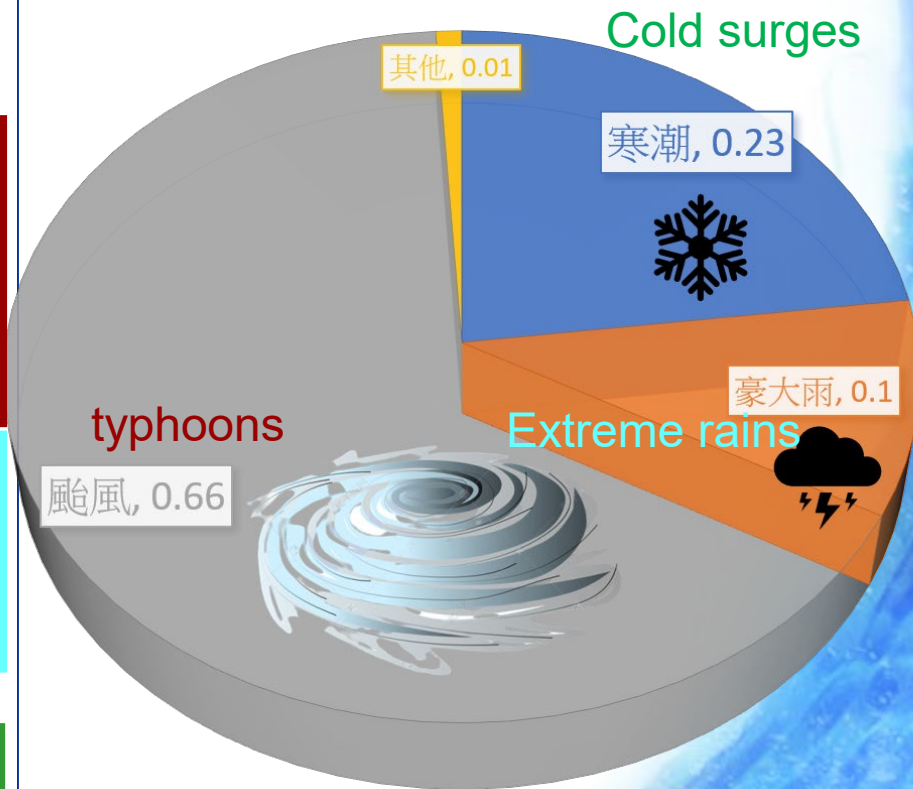
備註：農作物損失金額係以產地價格計算。

資料來源：行政院農業委員會畜牧處、農糧署、漁業署、林務局。

Note: The products loss by farm prices of production areas.

Source: Department of Animal Industry, Agriculture and Food Agency, Fisheries Agency, Forestry Bureau, COA, Executive Yuan.

## 台灣災害所占比例

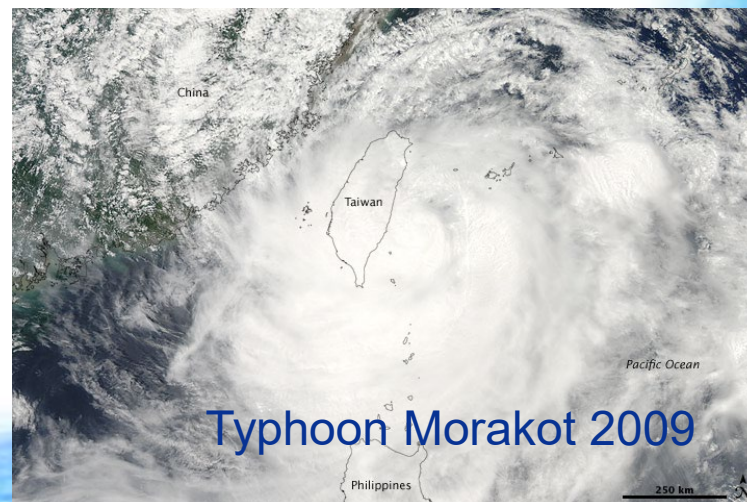


## Major natural disasters in Taiwan

- Typhoons
- Cold Surges
- Extreme rains

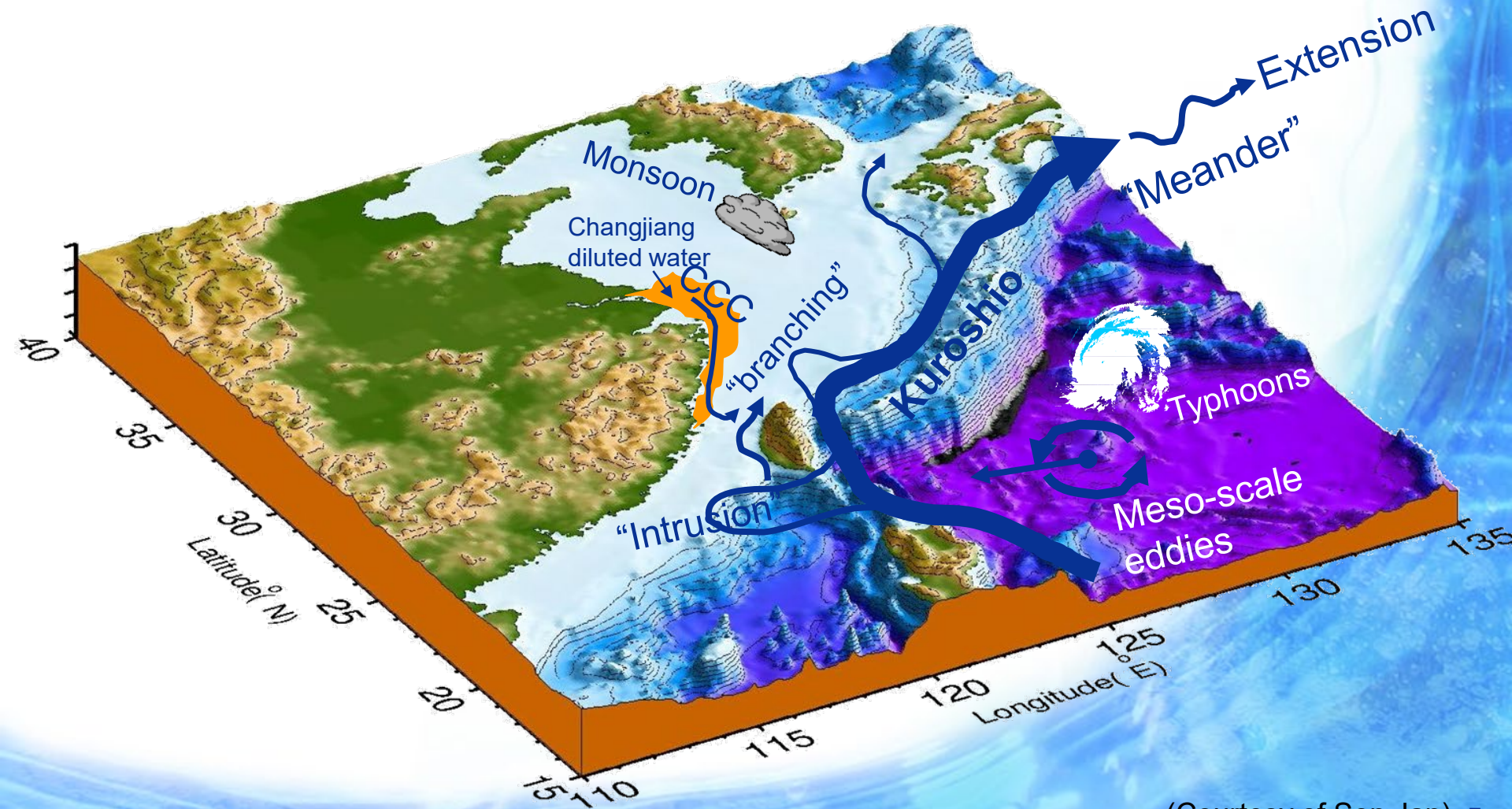
# Objective

- Build a **multi-scales**, **high-resolution** and **accurate** extend weather/climate forecast system
- Dynamical downscaling of regional ocean-atmosphere coupled model online driven by a global coupled model framework
  - Ocean and atmosphere
  - Extend weather forecast
  - Enhance short-term to long-term climate predictability skill
  - Benefit agriculture and fishery
  - Reduce the risks of natural disaster



# Paradise of physical oceanography

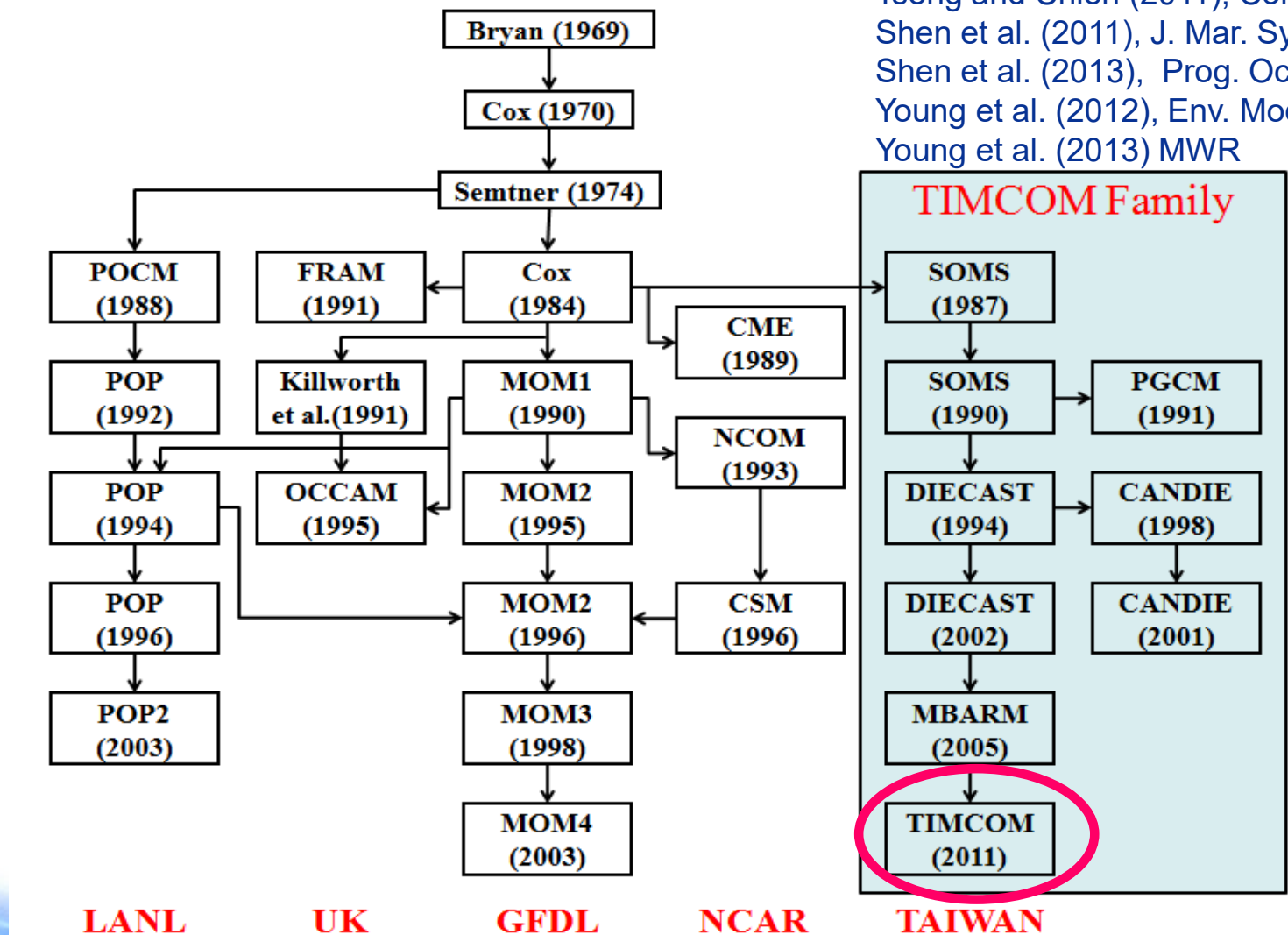
## Complicated circulation patterns in the East Asian seas



# Taiwan Multi-Scale Community Model (TIMCOM)

<http://140.112.66.144/research/timcom>

Tseng et al. (2012), Prog. Ocean  
Tseng and Chien (2011), Comp. Fluids  
Shen et al. (2011), J. Mar. Sys.  
Shen et al. (2013), Prog. Ocean  
Young et al. (2012), Env. Modell. Soft.  
Young et al. (2013) MWR



# Taiwan Multi-Scale Community Model (TIMCOM)

## Governing Equations

Continuity eqn. 
$$\frac{1}{R \cos \phi} \left( \frac{\partial u}{\partial \lambda} + \frac{\partial (v \cos \phi)}{\partial \phi} \right) + \frac{\partial \omega}{\partial z} = 0$$

$\lambda$ : the longitudinal variable  
 $\phi$ : the latitudinal variable  
 $z$ : the vertical variable

Momentum eqn.

$$\frac{\partial u}{\partial t} = -\mathcal{L}u + \left( f + \frac{u \tan \phi}{R} \right) v - \frac{1}{\rho_0 R \cos \phi} \frac{\partial p}{\partial \lambda} + D_m u + \frac{\partial}{\partial z} \left( A_u \frac{\partial u}{\partial z} \right)$$

$$\frac{\partial v}{\partial t} = -\mathcal{L}v - \left( f + \frac{u \tan \phi}{R} \right) u - \frac{1}{\rho_0 R} \frac{\partial p}{\partial \phi} + D_m v + \frac{\partial}{\partial z} \left( A_v \frac{\partial v}{\partial z} \right)$$

Conservation eqn. for temperature and salinity

$$\frac{\partial T}{\partial t} = -\mathcal{L}T + D_h T + \frac{\partial}{\partial z} \left( K_T \frac{\partial T}{\partial z} \right)$$

Eqn. of State

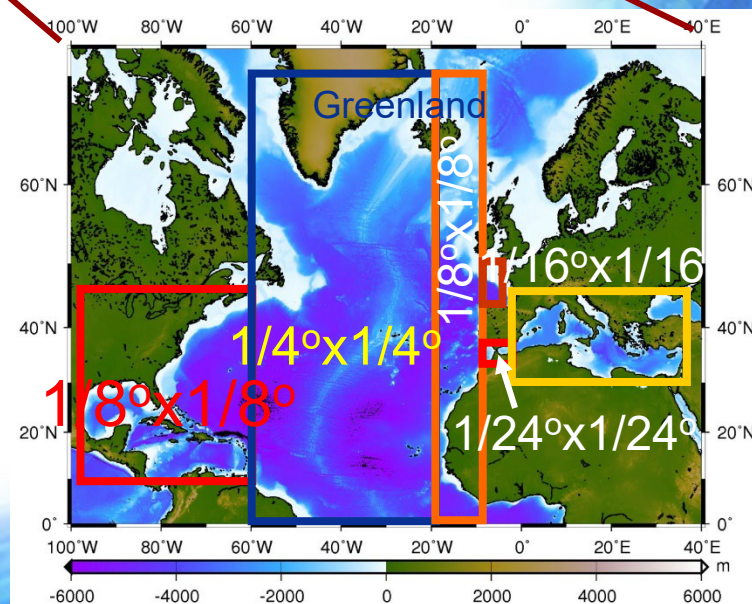
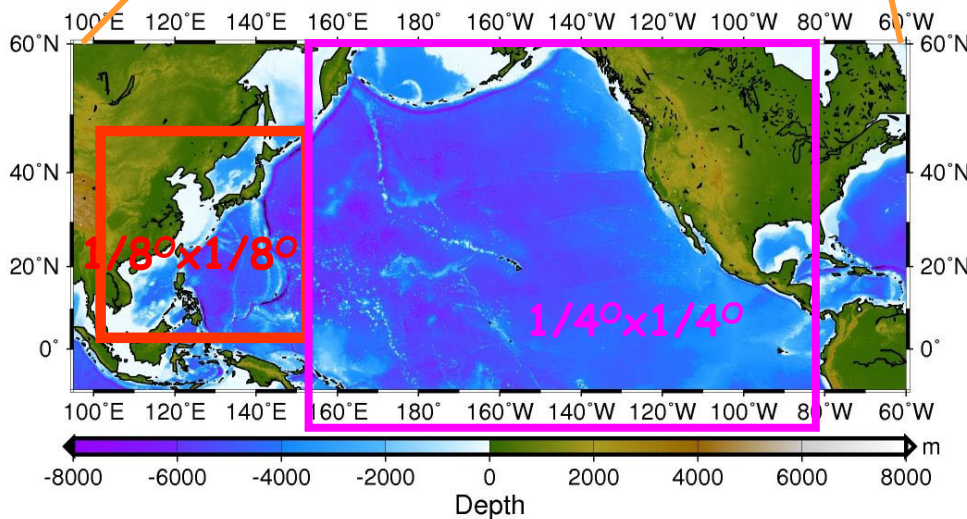
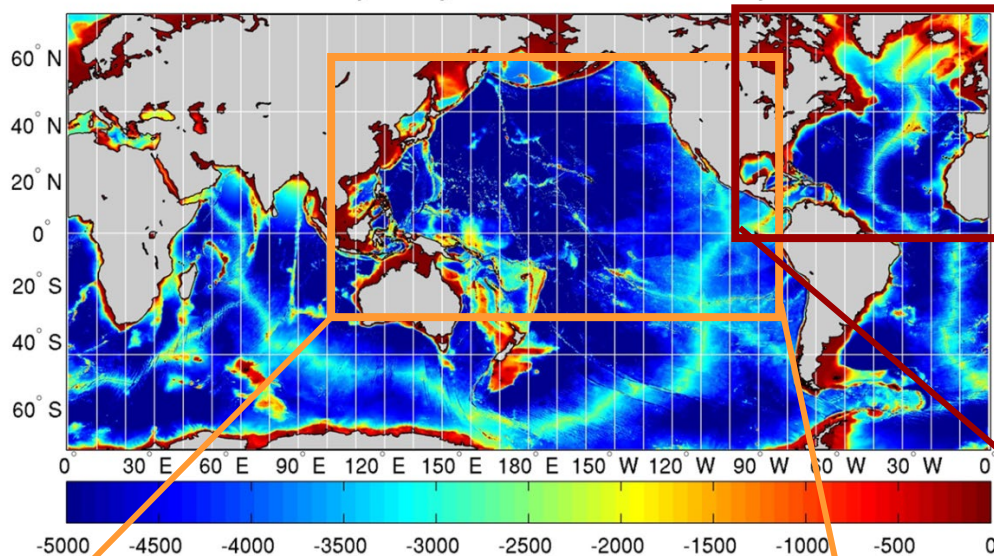
$$\rho = \rho(S, T, p)$$

Hydrostatic Eqn. 
$$\frac{\partial p}{\partial z} = -(\rho - \bar{\rho})g$$

$$D_{m(h)} = \frac{A_{m(h)}}{R^2} \left( \frac{1}{\cos^2 \phi} \frac{\partial^2}{\partial \lambda^2} - \tan \phi \frac{\partial}{\partial \phi} + \frac{\partial^2}{\partial \phi^2} \right) \quad \mathcal{L} = \frac{u}{R \cos \phi} \frac{\partial}{\partial \lambda} + \frac{v}{R} \frac{\partial}{\partial \phi} + \omega \frac{\partial}{\partial z}$$

# Taiwan Multi-Scale Community Model (TIMCOM)

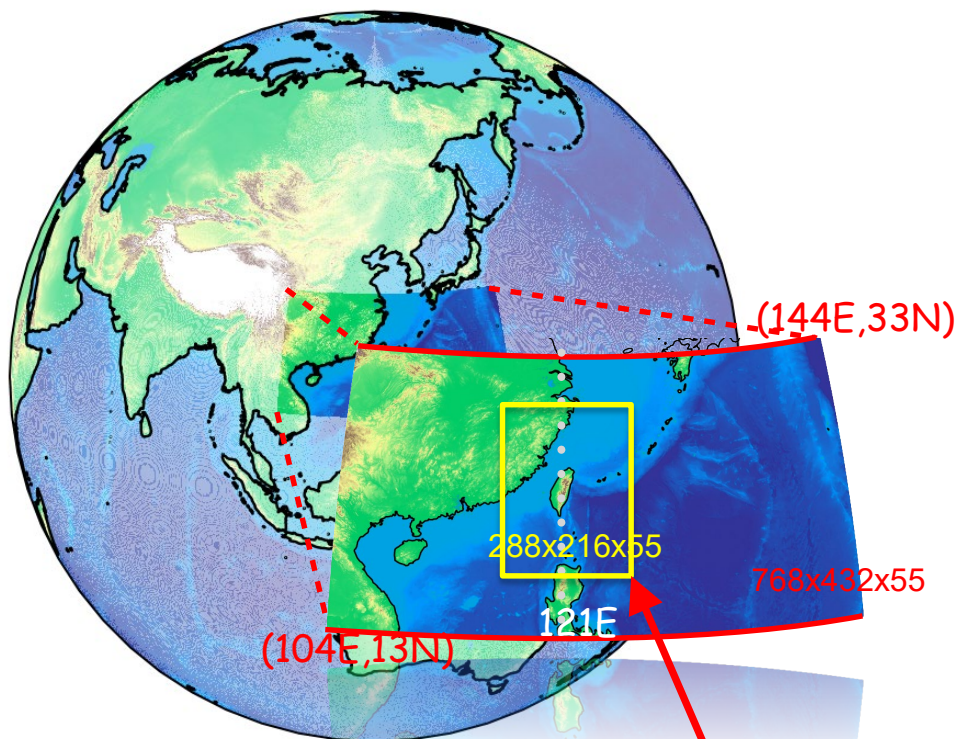
Model Bathymetry and Domain Decomposition



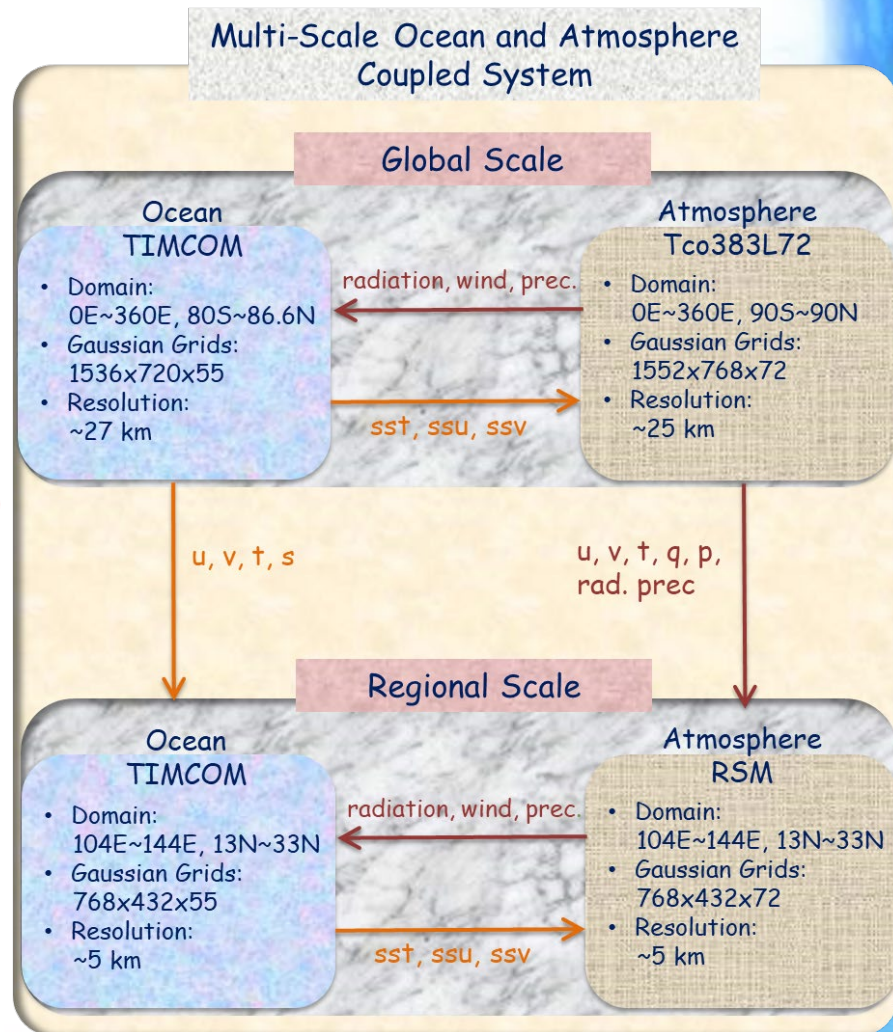
- Primitive, hydrostatic equation
- Fourth-order combined Arakawa A and C-grid
- Free surface
- KPP vertical mixing
- GM parameterization

# Multi-scale Ocean and Atmosphere Coupled Modeling System (MUSOCS)

high quality boundary condition from the global coupled model



**Regional domain (customizable)**



# Ocean-atmosphere coupled system in CWA

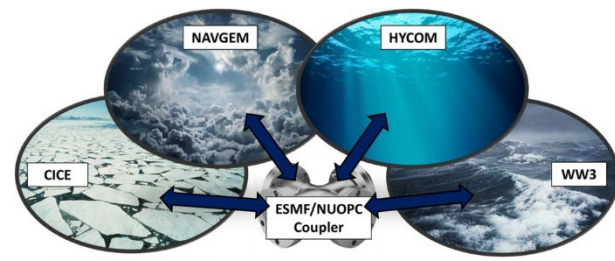
**Coupler is critical**

ESMF coupler

Decomposition and Reorganization

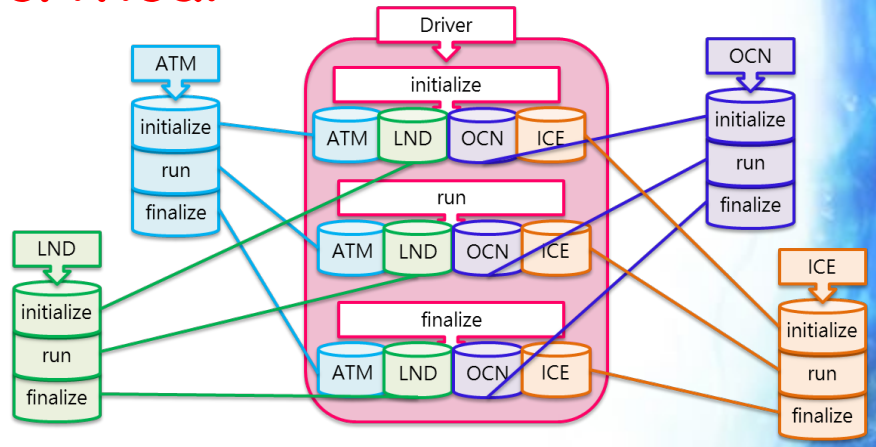
Advantage:

1. Flexible
2. Division



Disadvantage:

1. steep learning/developing curve



NTU&CWA coupler

**MULTi-Scale Ocean and Atmosphere Coupled modelling system(MUSOACS)**

Collection and Connection

Advantage:

1. Customization
2. Easy to use
3. Efficiency

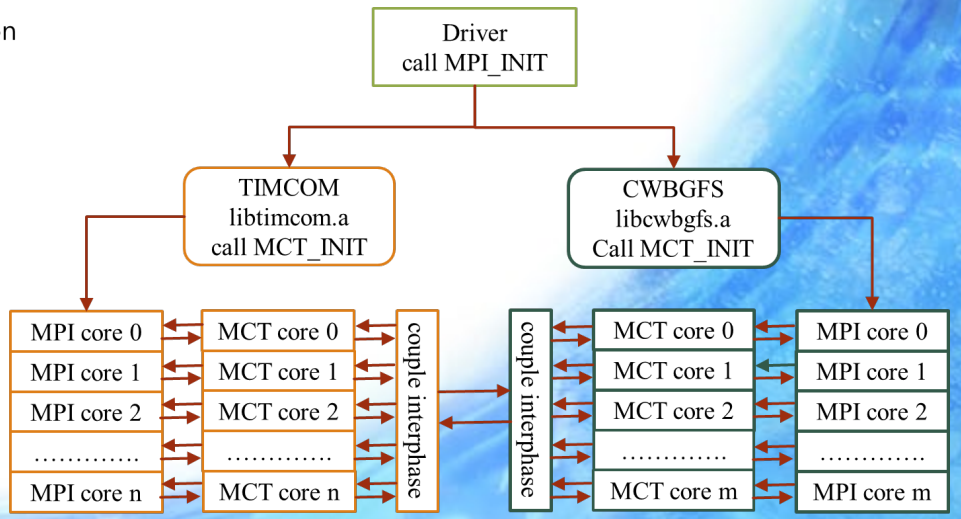
Disadvantage:

1. Complicated if there are many components

Single execution driver

components

infrastructure



coupler data flow

# Ocean-atmosphere coupled system in CWA

Version & Resolution

**GEPSv3**

Tco383L72(0.235°)  
TIMCOMv3.1(0.237°)

RSM(5km)  
TIMCOMv3.1(5km)

GVER: EMC Verification Scorecard

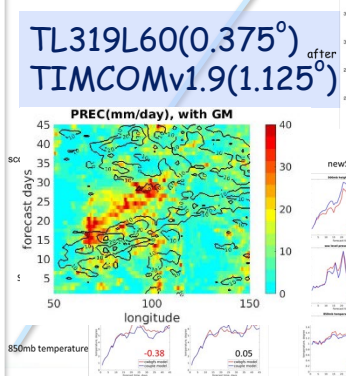
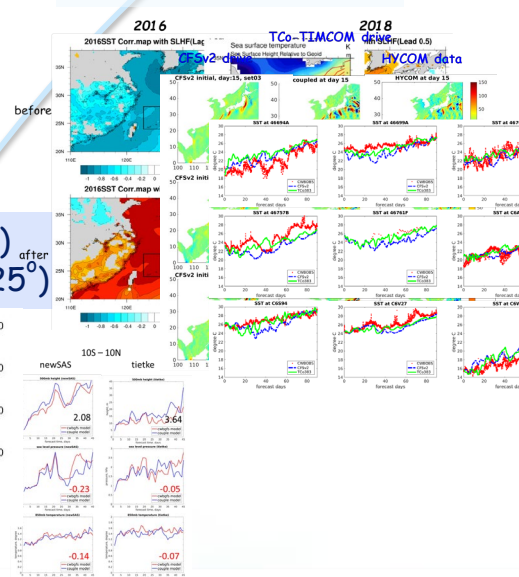
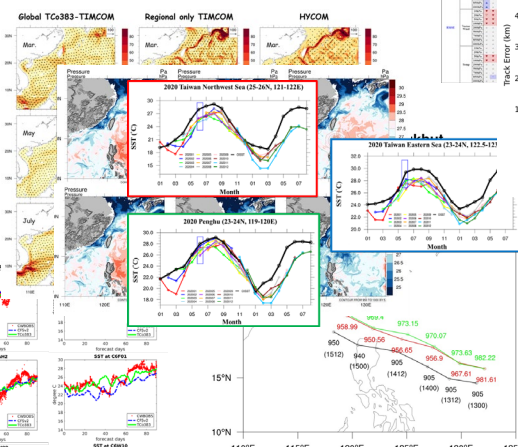
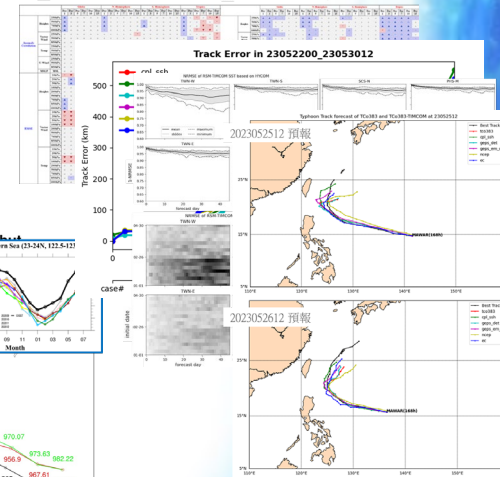
Tco383L72(0.235°)  
TIMCOMv2.1(0.237°)

RSM(8km)  
TIMCOMv1.8(8km)

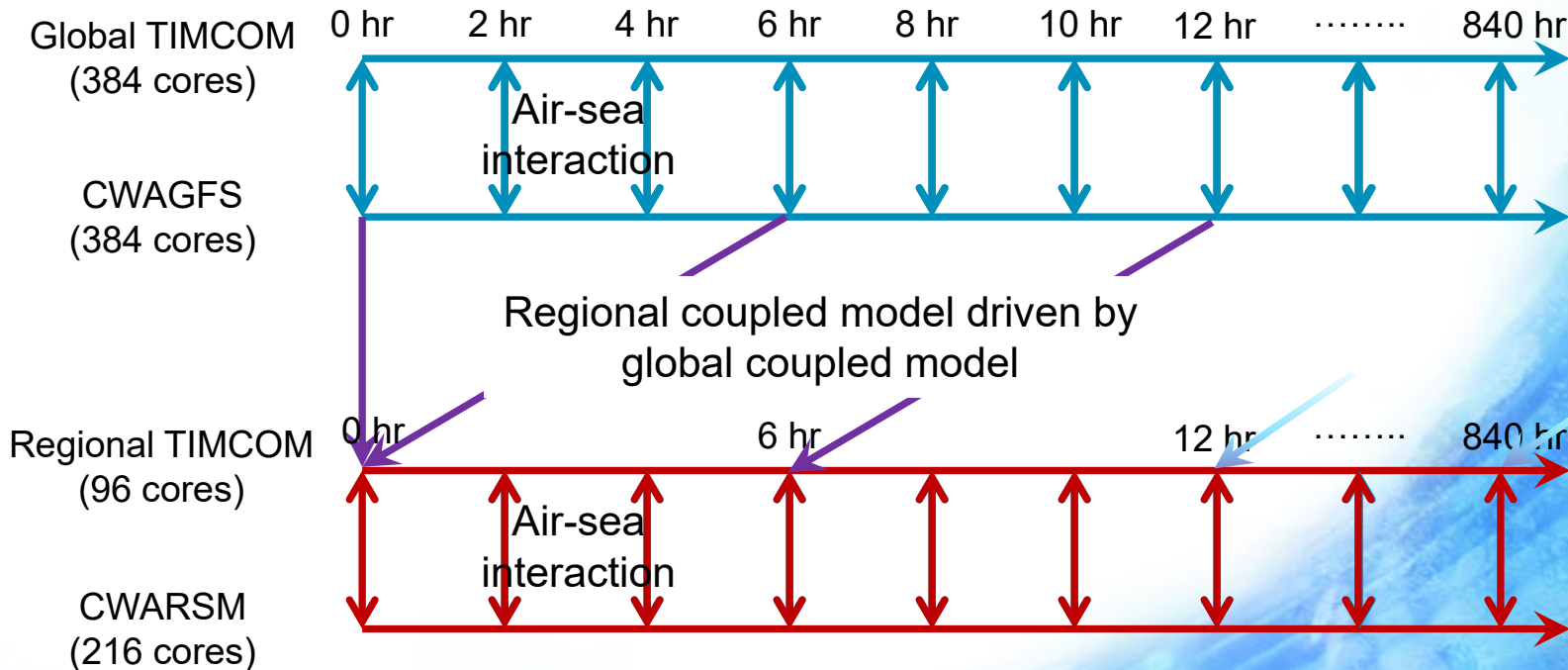
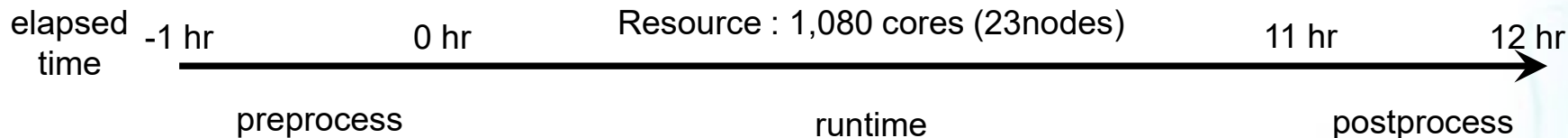
TL319L60(0.375°)  
TIMCOMv1.9(0.375°)

TIMCOMv1.8(0.125°)

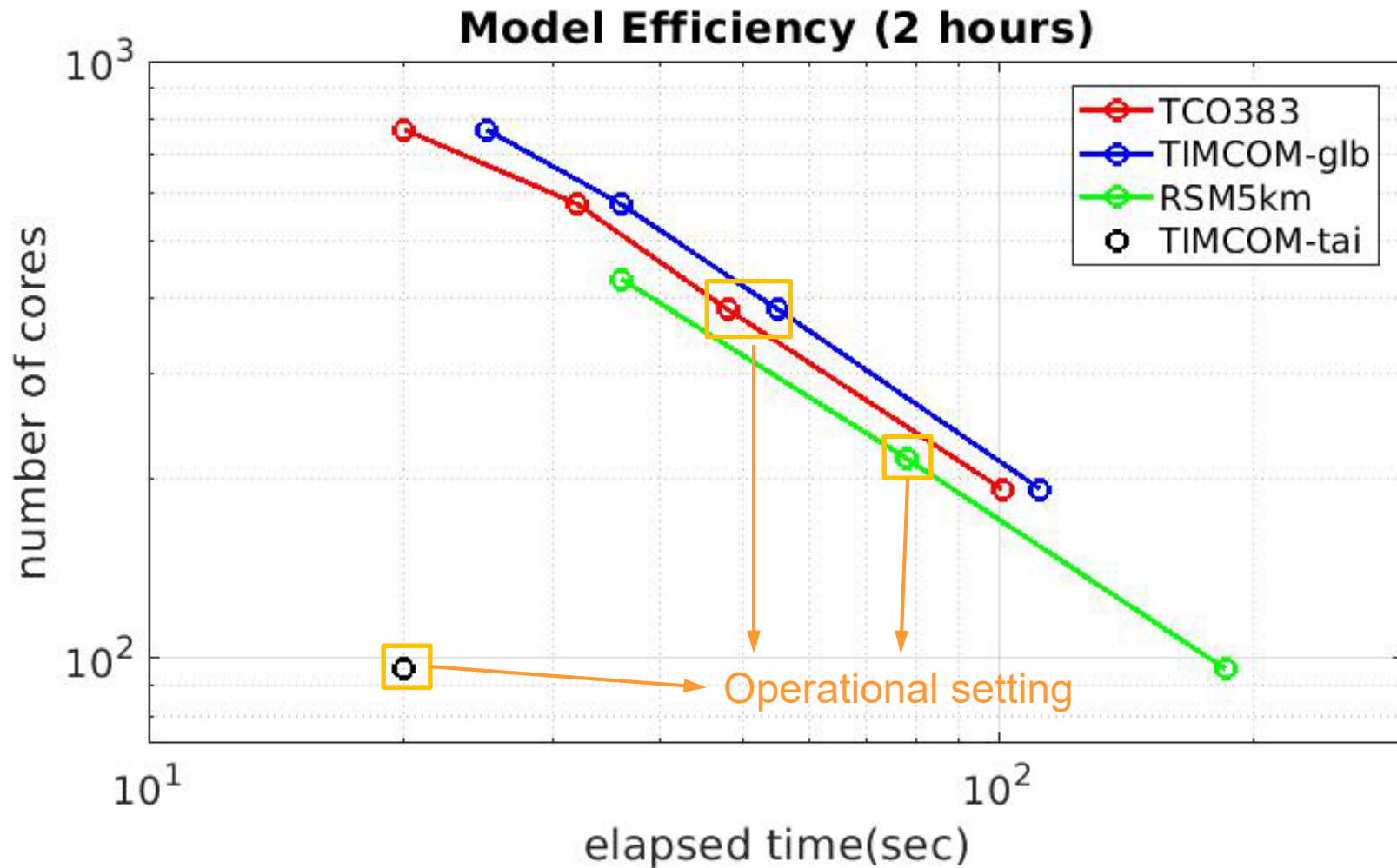
Tco383 compare with GEPS2.0.1    Tco383-TIMCOM compare with GEPS2.0.1



# Operational parallel run in CWA



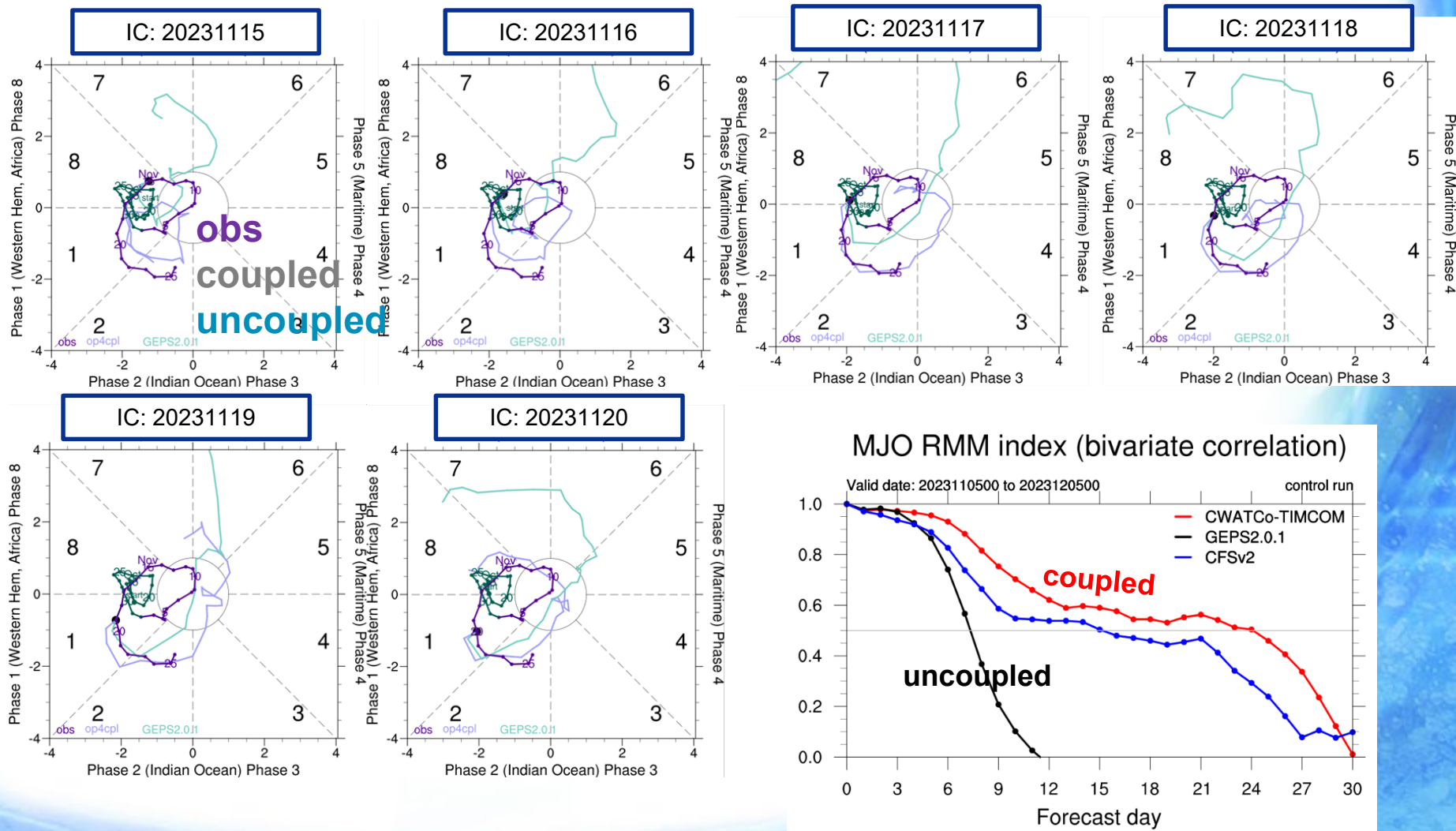
# Model performance



# Validation



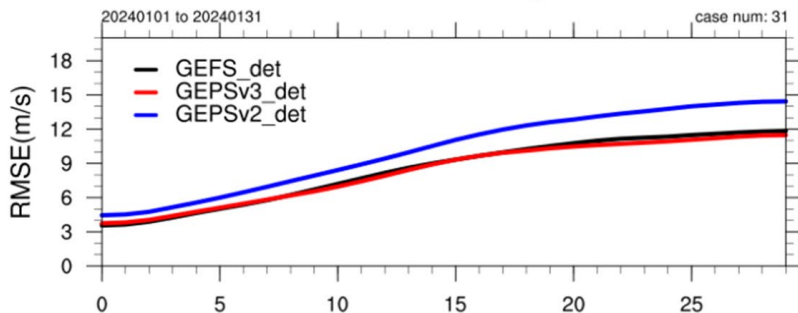
# Global coupled vs. uncoupled Intraseasonal Oscillation- MJO



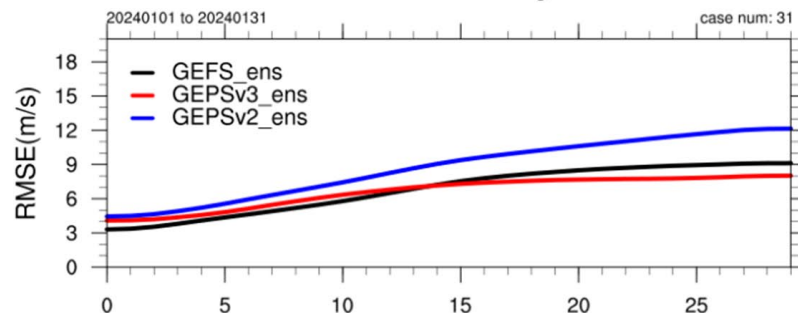
# Global coupled vs. uncoupled vs. NCEP GEFS

2024/01/01-2024/01/31 (15°S-15°N)

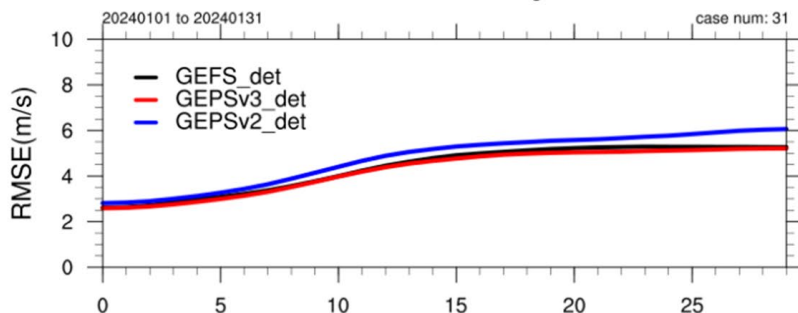
## U200 anomaly



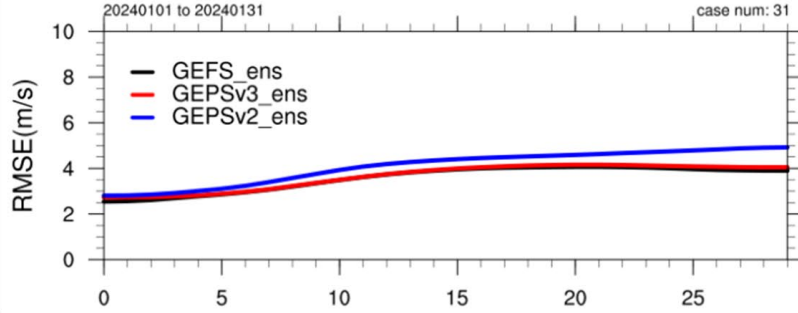
## U200 anomaly



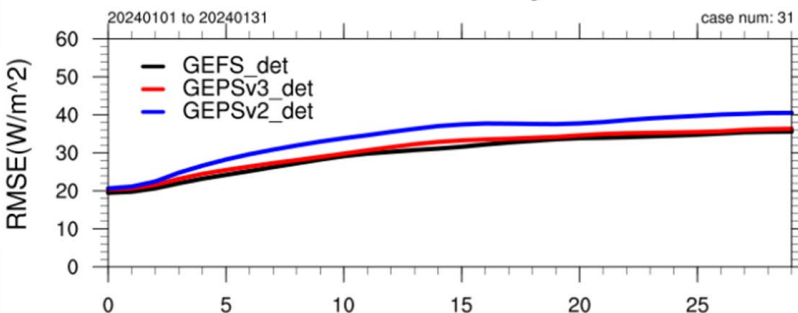
## U850 anomaly



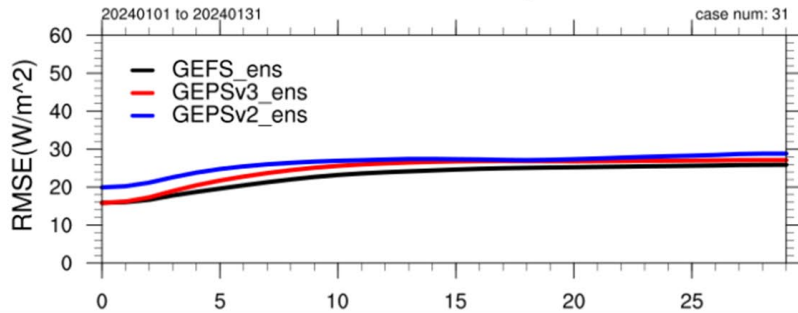
## U850 anomaly



## OLR anomaly



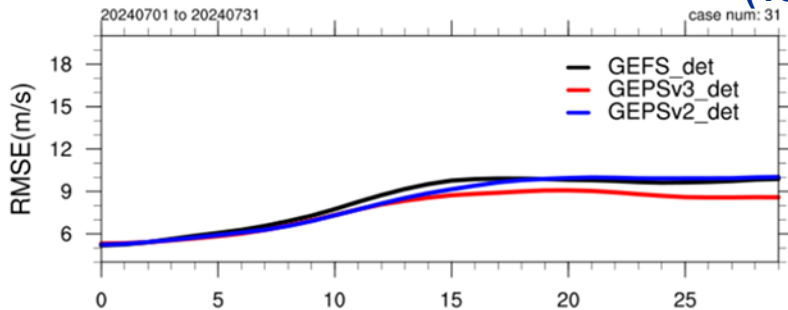
## OLR anomaly



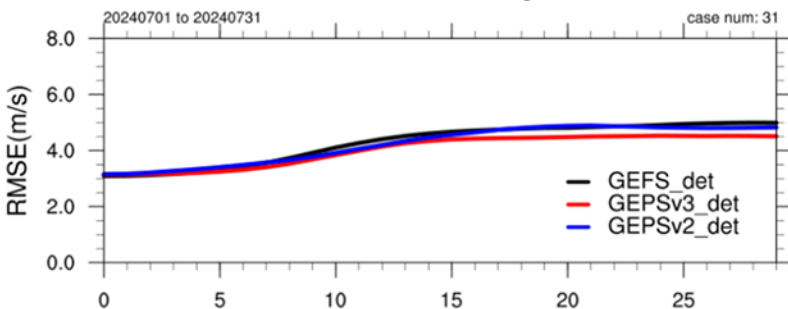
# Global coupled vs. uncoupled vs. NCEP GEFS

2024/07/01-2024/07/31  
(15°S-15°N)

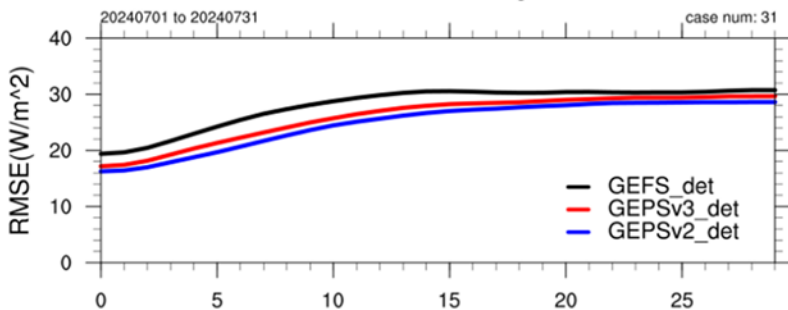
## U200 anomaly



## U850 anomaly

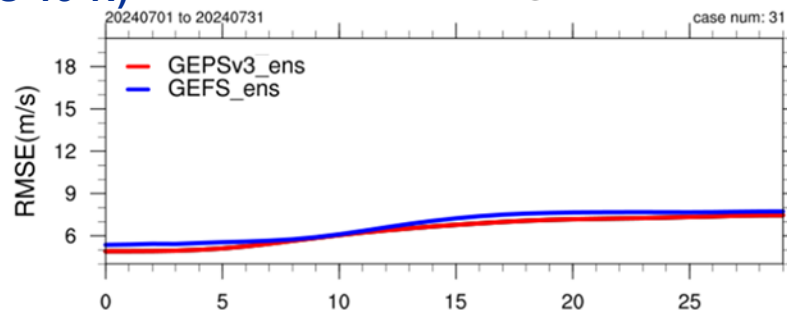


## OLR anomaly

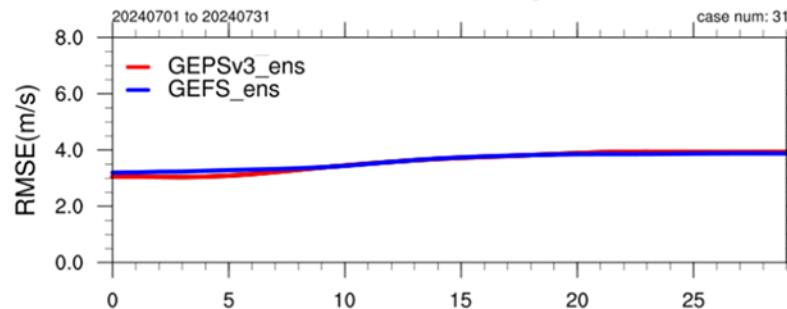


# Global coupled vs. NCEP GEFS

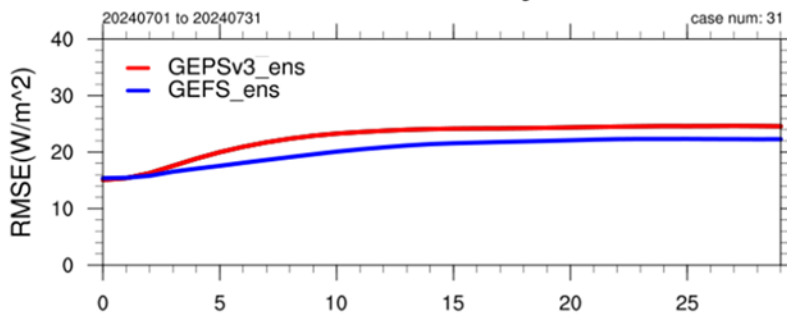
## U200 anomaly



## U850 anomaly

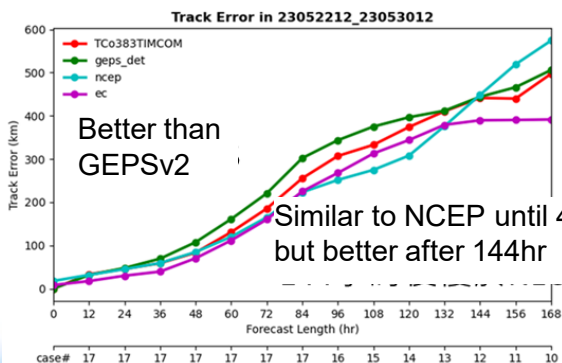
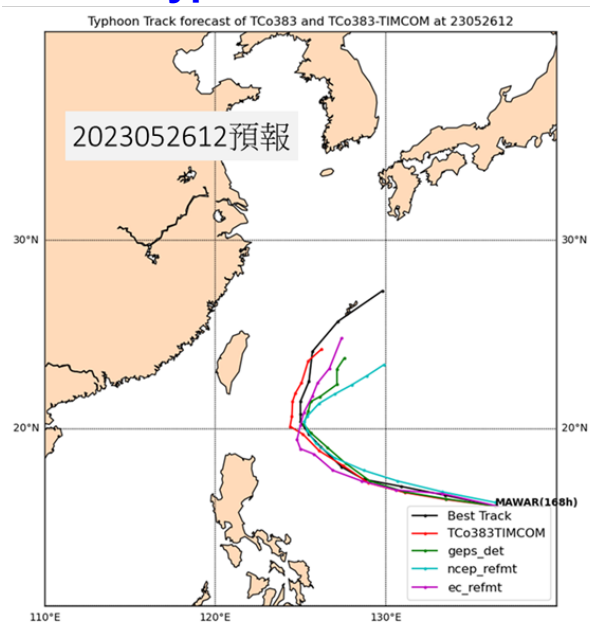


## OLR anomaly

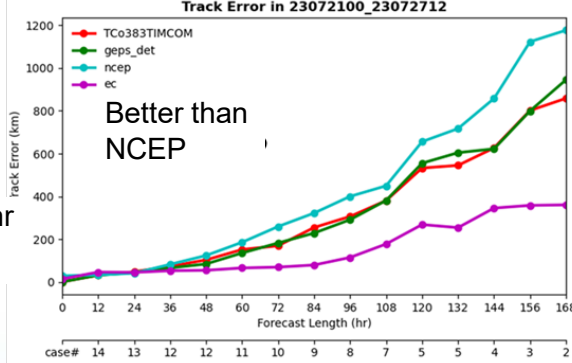
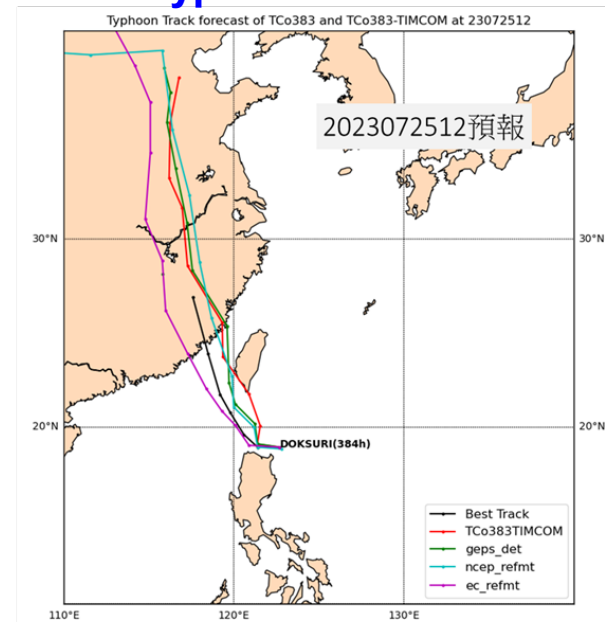


# Global coupled vs. uncoupled Typhoon Track

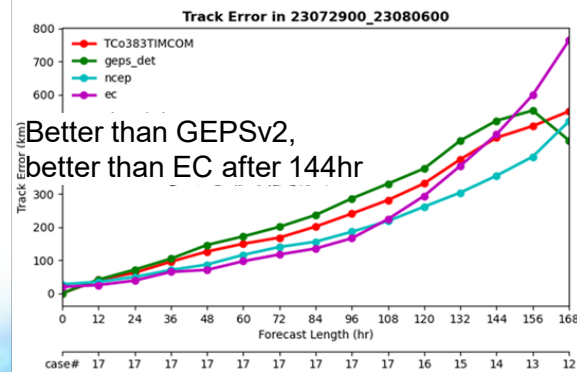
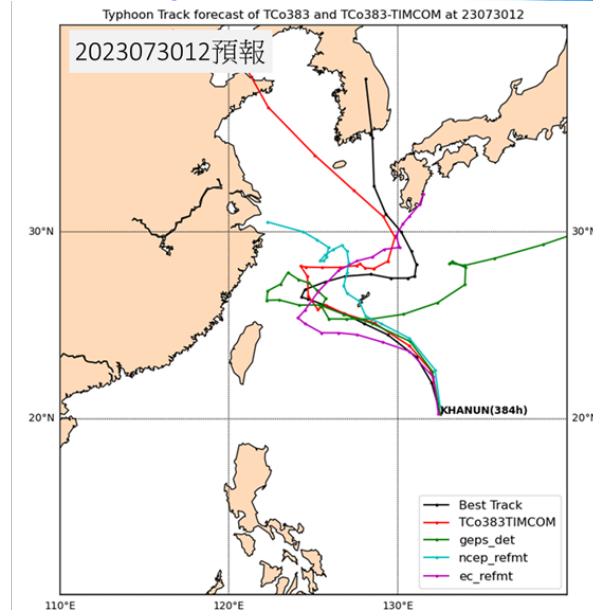
## Typhoon Mawar



## Typhoon Doksuri



## Typhoon Khanun

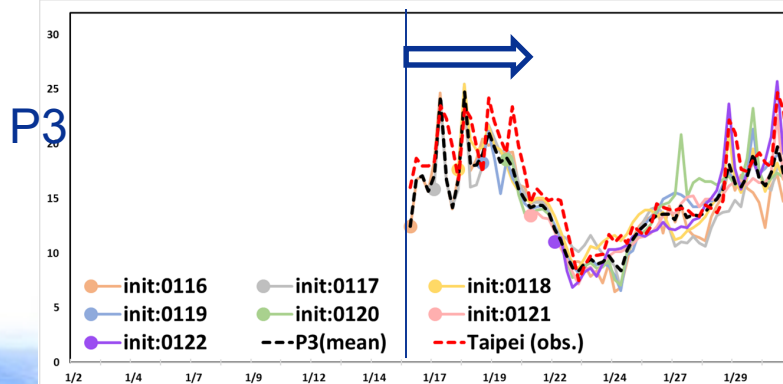
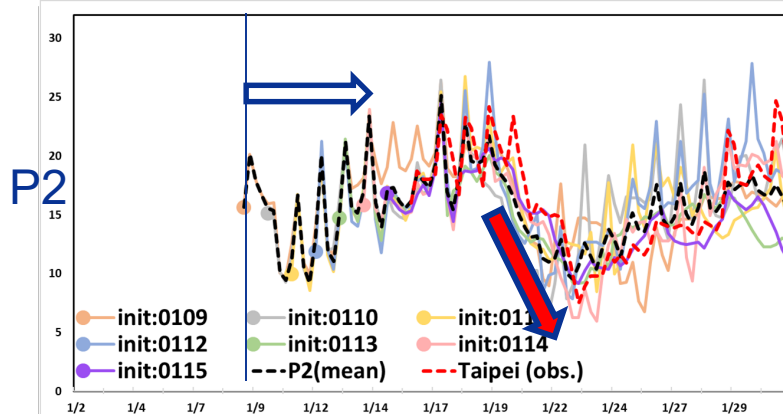
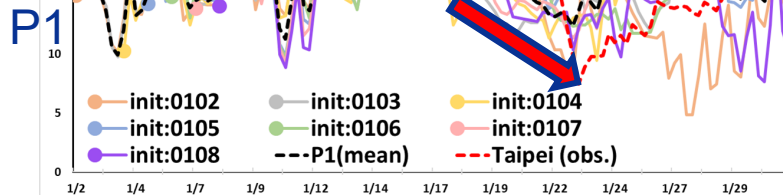
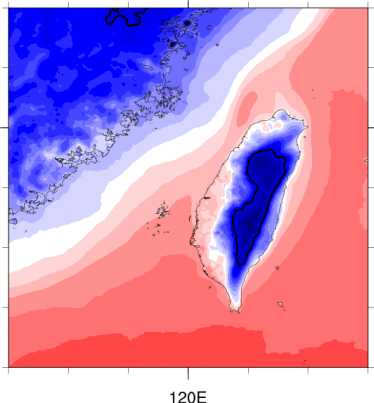


# 2024 1/23 cold surge event

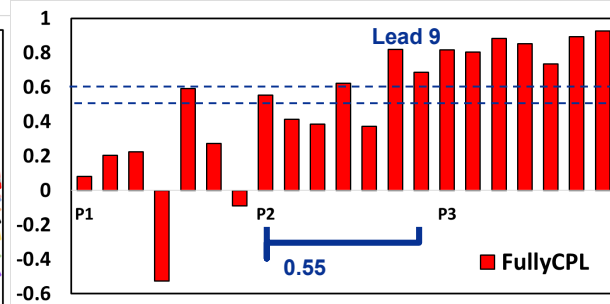
Initial time : 2024/01/17 00Z

RSM T2m of 10°C isotherm

2024/01/17



Corr: 1/22-1/31



P1 : initial 01/02 to 01/08  
P2 : initial 01/09 to 01/15  
P3 : initial 01/16 to 01/22

P1 : weak signal  
P2 : signal arise  
P3 : accurately predict

# 2024 cold surge events

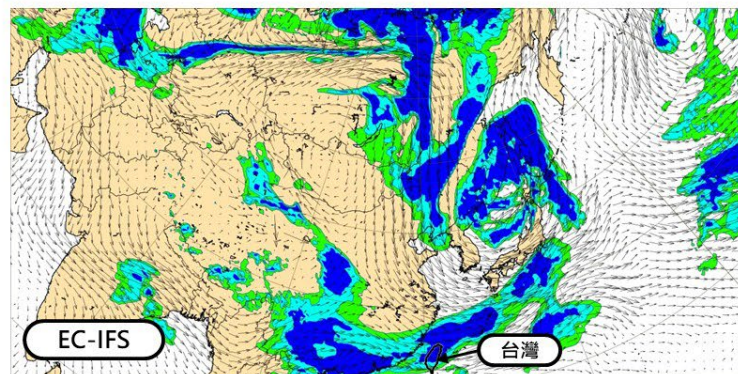
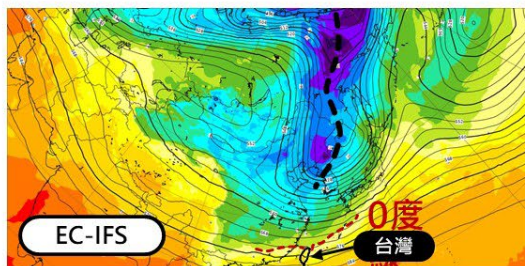
[即時分析] 20240122-0125 寒潮爆發

2024.01.23

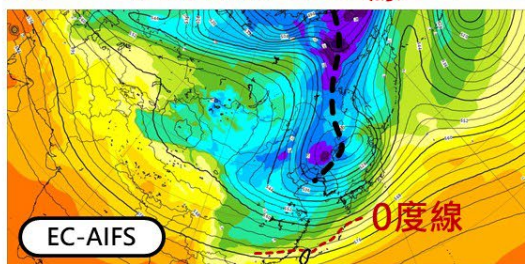
850hPa溫度場&500hPa重力位高度場

700hPa風場&相對濕度場

IFS

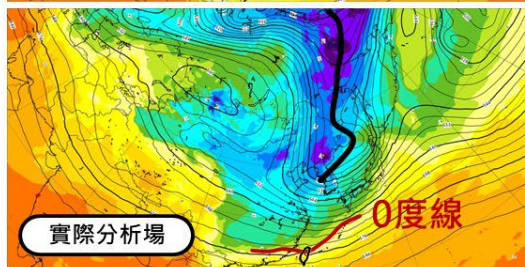


AIFS



比較EC-IFS (數值) 以及AIFS (AI) 模式, 850 hPa 溫度場 0 度線位置, 與 500 hPa 重力位高度場槽脊配置差異不大, 且實際分析場相似。

Analysis



**AI 模式5 日前即掌握本波寒流。**

此外, 700hPa相對濕度場亦顯示受華南雲雨帶影響, 臺灣附近水氣偏多, 故本波寒流之天氣型態以降水較多之**濕冷**為主。

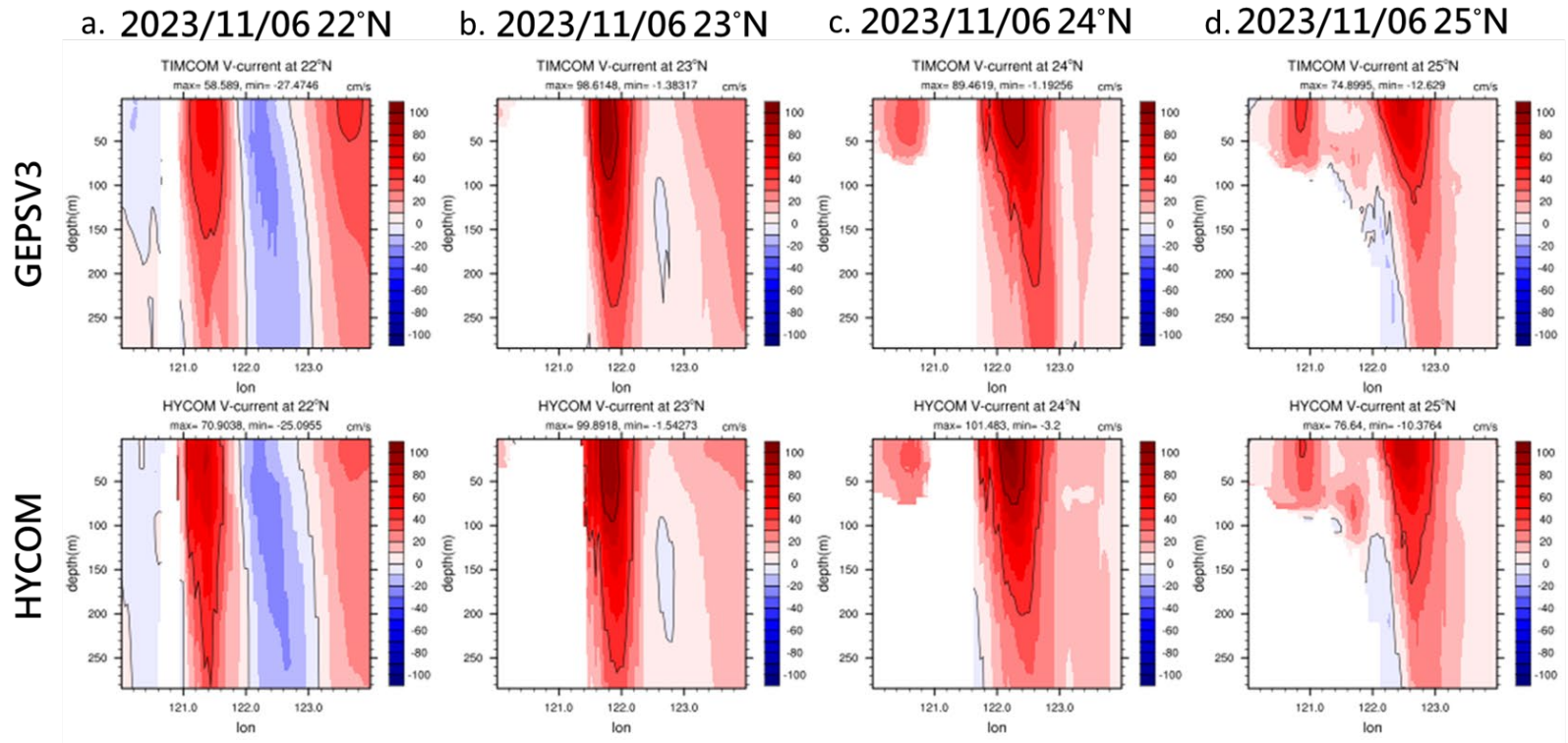
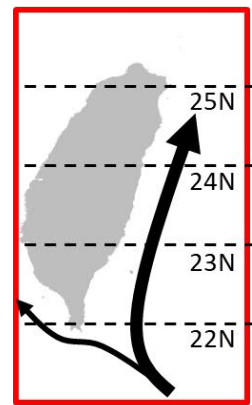
圖資來源 | ECMWF

初始時間: 2024/01/18 12Z  
預報時間: 2024/01/23 00Z(+84h)

Dynamical model actually performs better forecast skill than AI model.

# GEPSv3 (Regional TIMCOM) vs HYCOM(0.08°) reanalysis

Initial time : 2023/11/01 00Z  
 Forecast time : 2023/11/06 00Z(+120h)



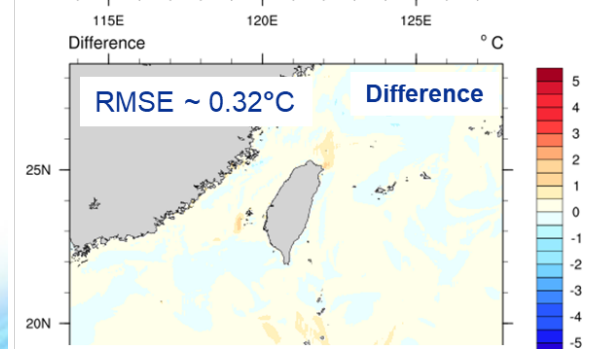
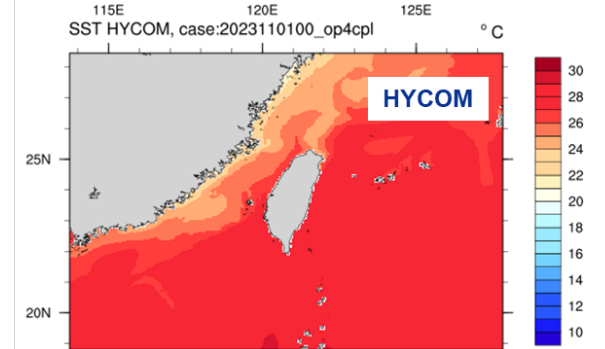
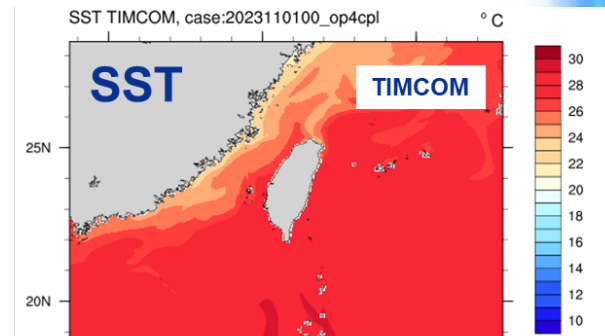
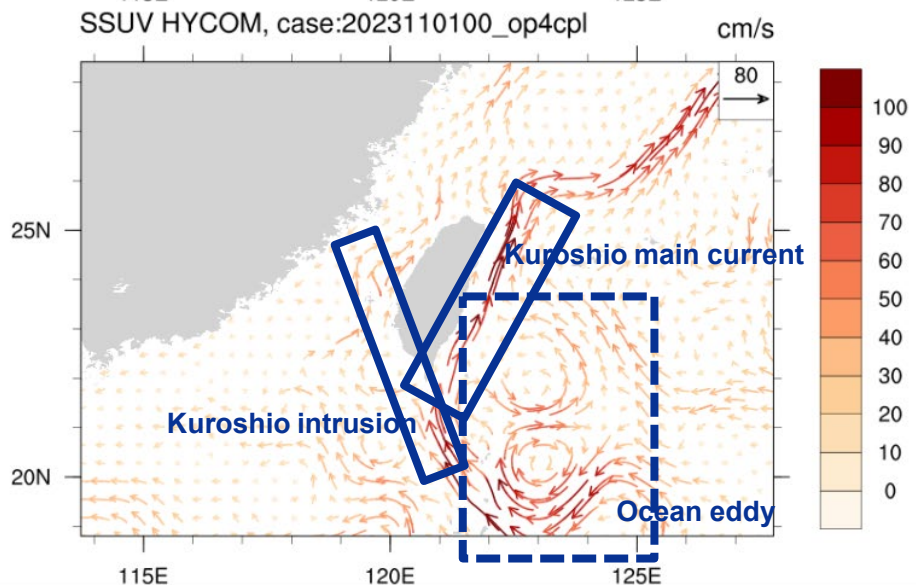
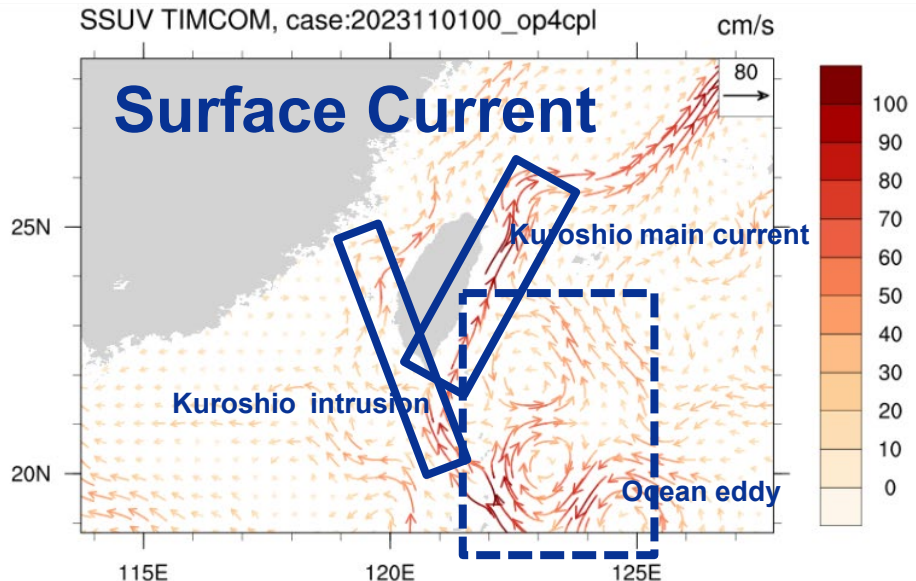
# VS HYCOM reanalysis (Surface)

Initial time : 2023/11/01 00Z

Forecast time : 2023/11/06 00Z(+120h)

TIMCOM

HYCOM



RMSE : HYCOM forecast ~0.76 °C

## Summary

- A novel Multi-scale Ocean and Atmosphere Coupled Modeling System (MUSOACS) is developed to enhance the predictability of extended-range weather/climate forecasts
- MUSOACS: high-performance global ocean+atmos coupled models + regional coupled model (2+2)
- MUSOACS surpasses the current operational atmospheric forecast system at CWA up to 16 days
- The predictability of MJO is enhanced.
- Typhoon tracks are comparable with EC and NCEP products

Thanks for Your Attention!

