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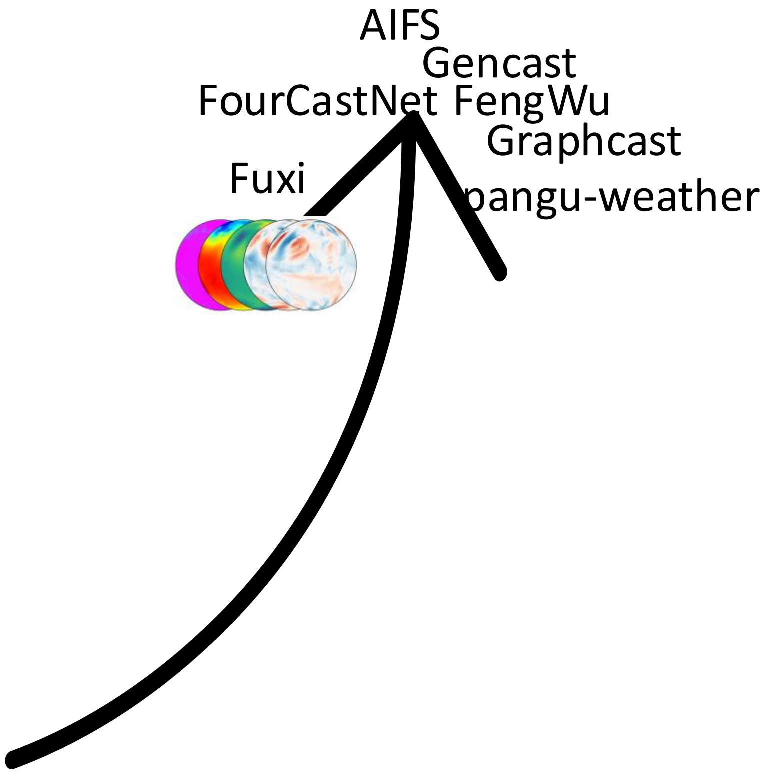
# OceanBench: A Benchmark for Data-Driven Global Ocean Forecasting systems

Anass El Aouni, Quentin Gaudel, Yann Drillet,
Marie Drevillon, Simon Van Gennip, Pierre-Yves Le Traon, Alain Arnaud

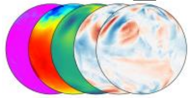
aelaouni@mercator-ocean.eu

# AI-Atmosphere



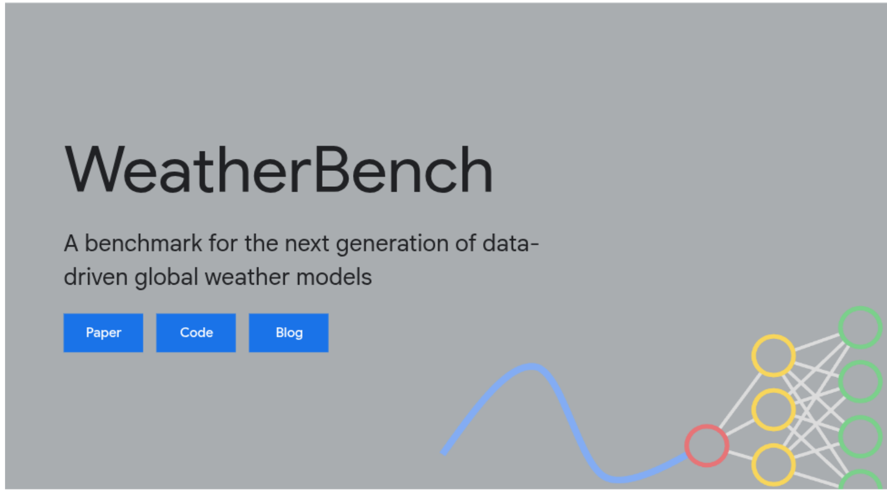
# AI-Atmosphere

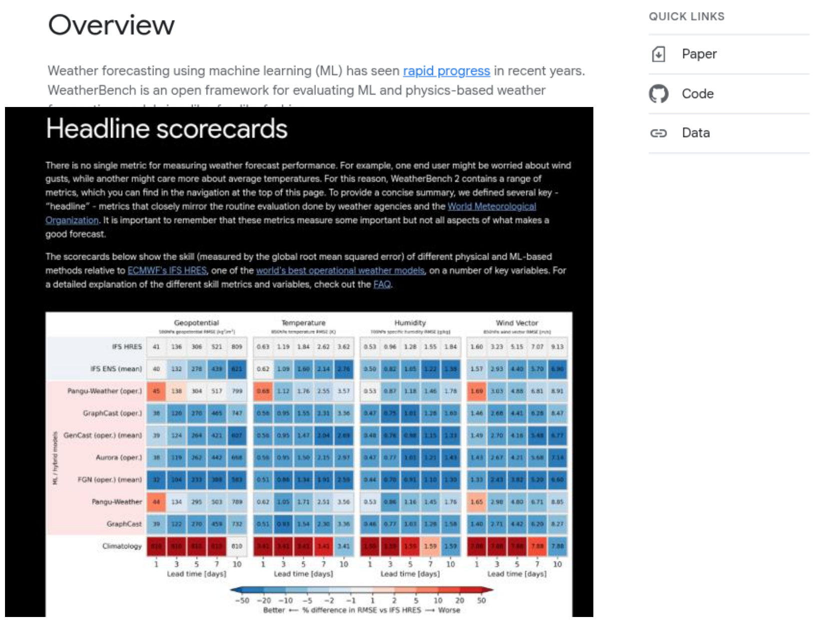
AIFS
Gencast
FourCastNet FengWu
Graphcast
Fuxi
pangu-weather



weatherbench
weatherbench2
weatherbenchX

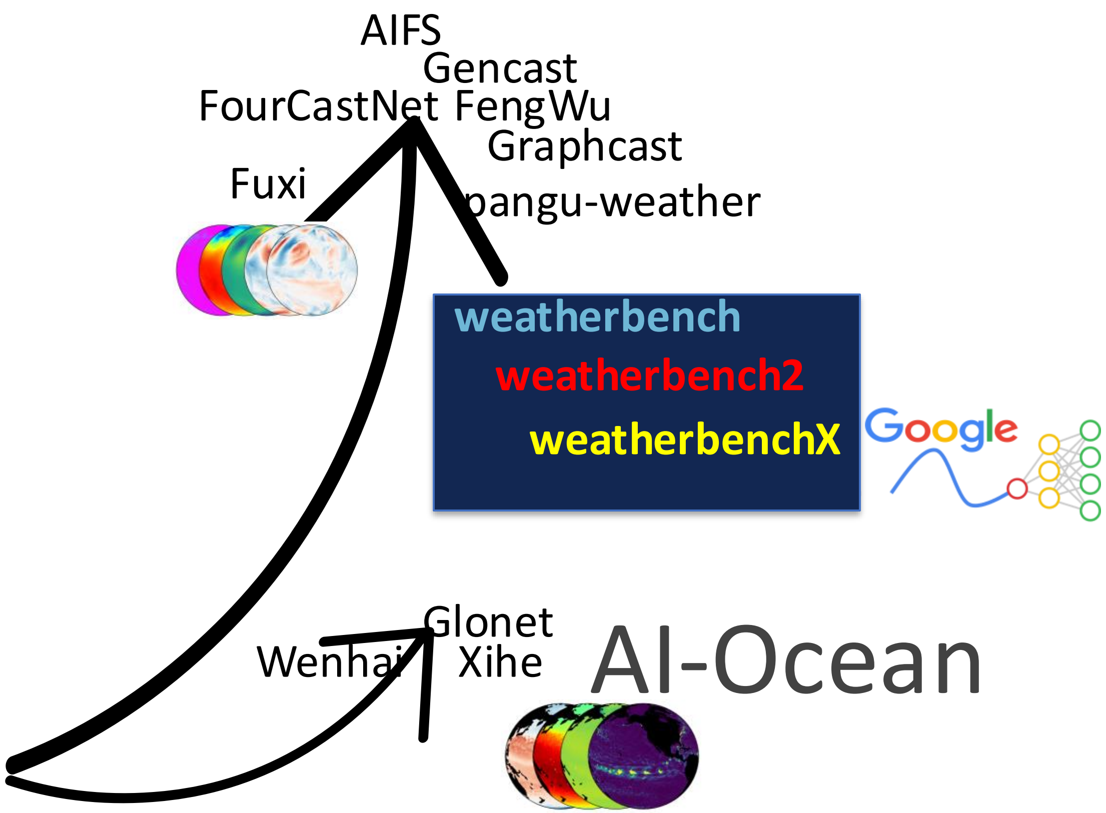
Google

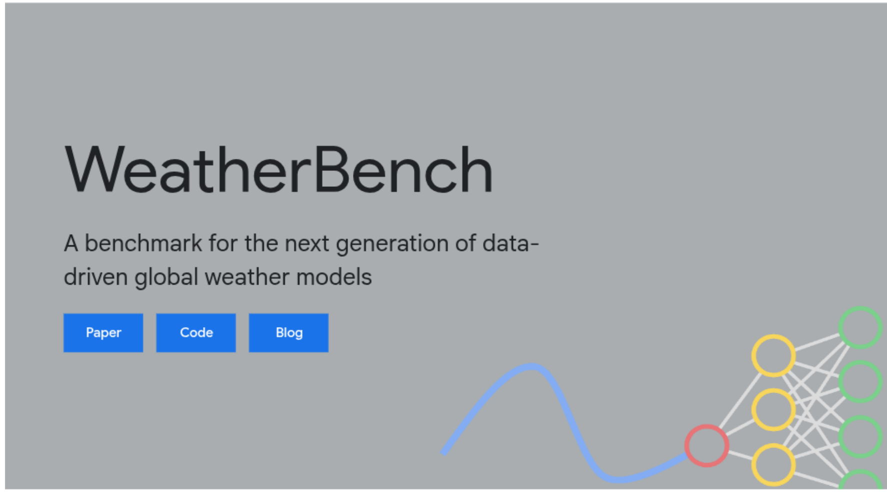


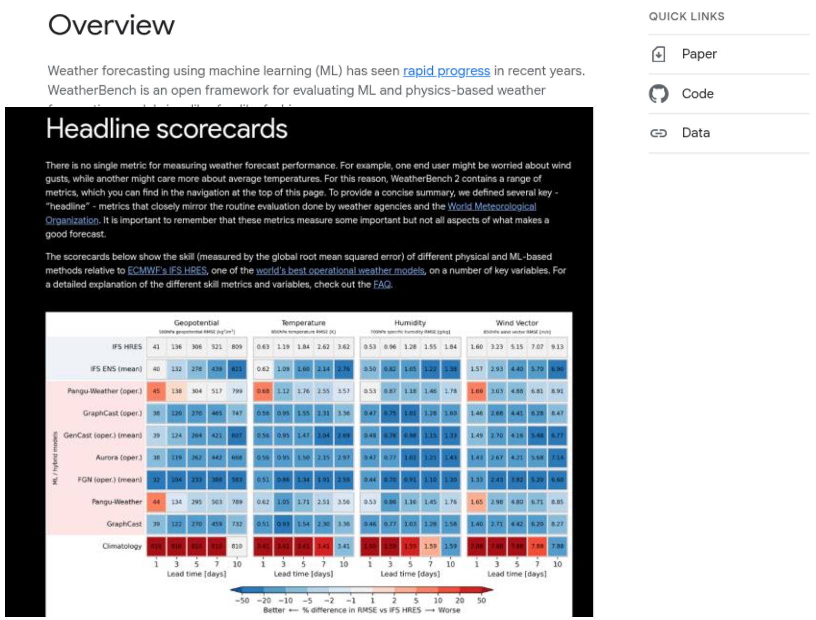



# Forecasting systems & benchmarking

## AI-Atmosphere

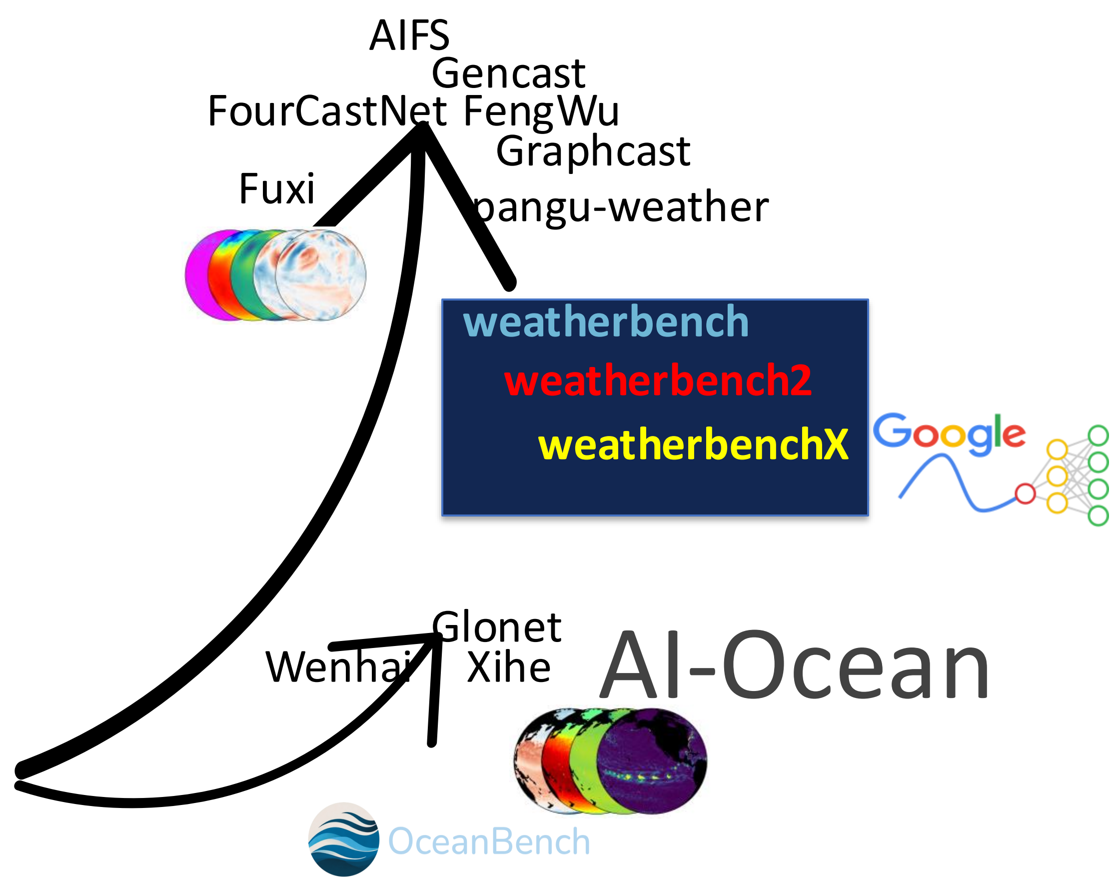


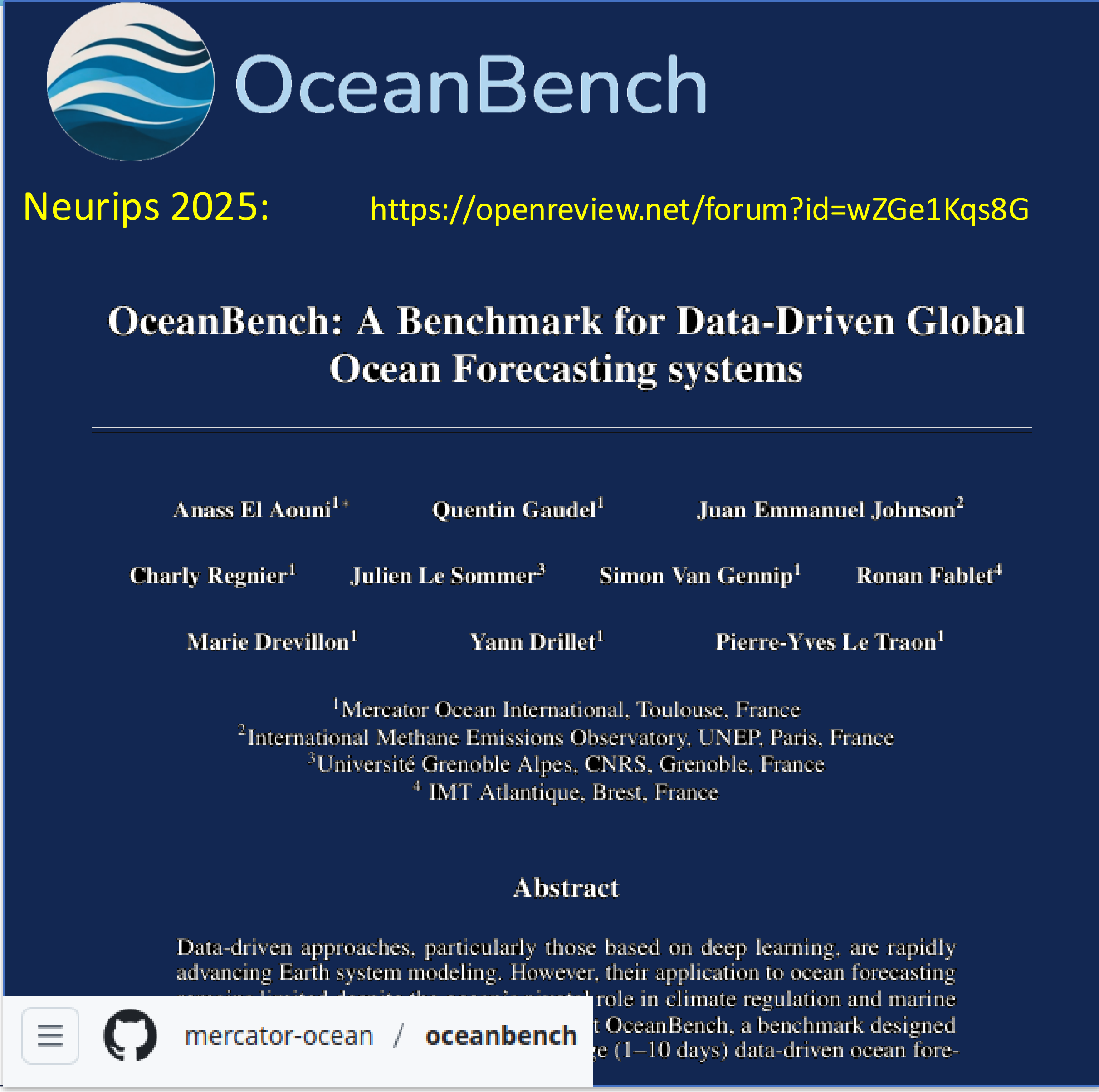



# OceanBench: A Benchmark for Data-Driven Global Ocean Forecasting systems

## AI-Atmosphere





OceanBench

Neurips 2025: https://openreview.net/forum?id=wZGe1Kqs8G

**OceanBench: A Benchmark for Data-Driven Global Ocean Forecasting systems**

Anass El Aouni[1*] Quentin Gaudel[1] Juan Emmanuel Johnson[2]
Charly Regnier[1] Julien Le Sommer[3] Simon Van Gennip[1] Ronan Fablet[4]
Marie Drevillon[1] Yann Drillet[1] Pierre-Yves Le Traon[1]

[1]Mercator Ocean International, Toulouse, France
[2]International Methane Emissions Observatory, UNEP, Paris, France
[3]Université Grenoble Alpes, CNRS, Grenoble, France
[4] IMT Atlantique, Brest, France

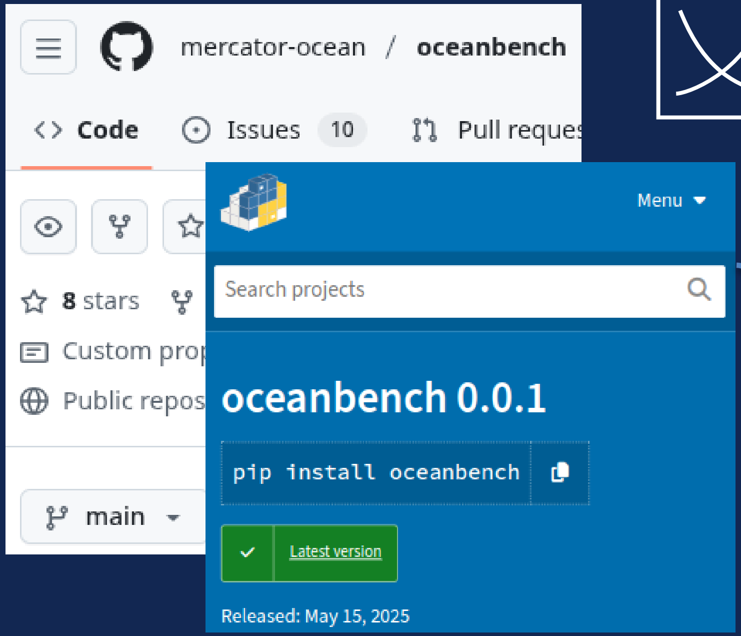
**Abstract**

Data-driven approaches, particularly those based on deep learning, are rapidly advancing Earth system modeling. However, their application to ocean forecasting ... role in climate regulation and marine ... t OceanBench, a benchmark designed ... e (1–10 days) data-driven ocean fore-

mercator-ocean / oceanbench

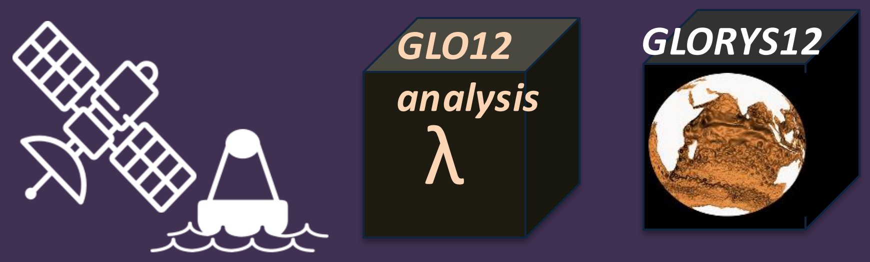
# OceanBench: A Benchmark for Data-Driven Global Ocean Forecasting systems

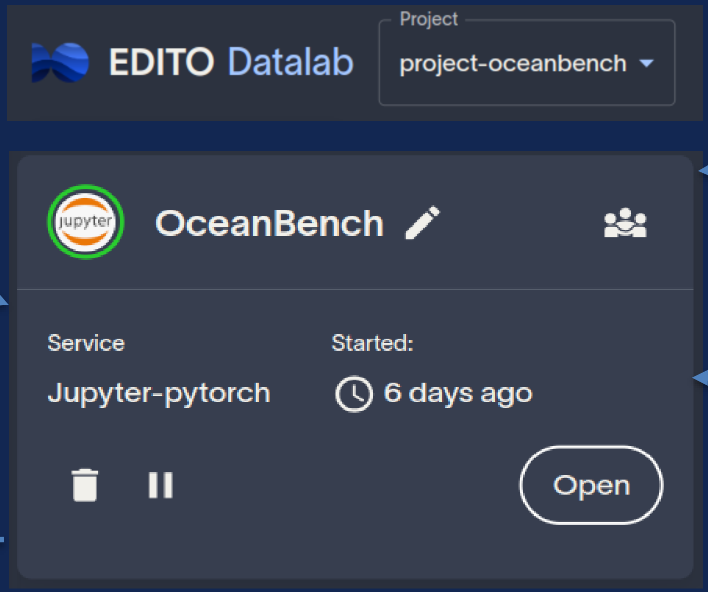




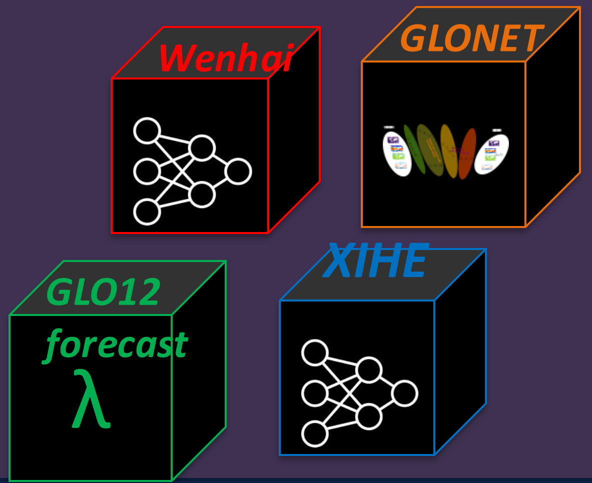

github.com/mercator-ocean/oceanbench

## References



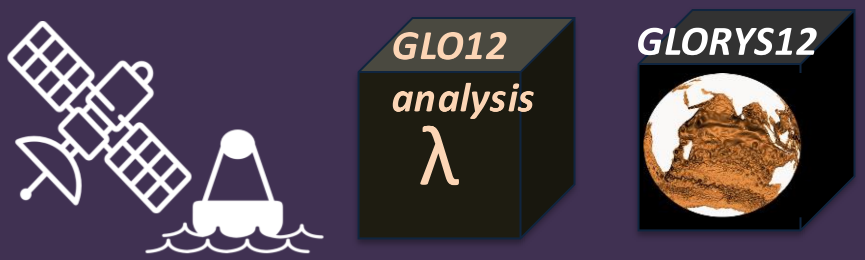




## Candidates




# OceanBench: Datasets

*dataset/references*




## Benchmarking

### Initialization (EDITO)

- GLO12 hindcast (EDITO)
  - zos, so, thetao, uo, vo…
  - 2024
- IFS
  - u10,v10,t2m, mslp, sp..

### References (EDITO)

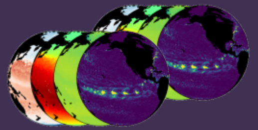
- GLORYS12 2024
- GLO12 analysis 2024
- Observaration (2024)
  - Satellite and in situ

### Training (CMC, CAMS..)

- GLORYS12
  - zos, so, thetao, uo, vo
  - 1993~2020
- ERA5/IFS….

# OceanBench: Challengers

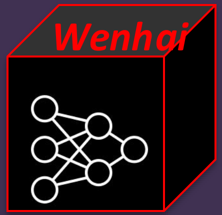
## Candidates



## ML-based models


Wang, Xiang, et al.
"Xihe:  arXiv:2402.02995 (2024).


El Aouni, Anass, et al. " Journal of Geophysical Research: Machine Learning and Computation 2.3 (2025): e2025JH000686.




Cui, Yingzhe, et al. "Forecasting the eddying ocean with a deep neural network." Nature Communications 16.1 (2025): 2268.

## physics-based models

**Baseline**

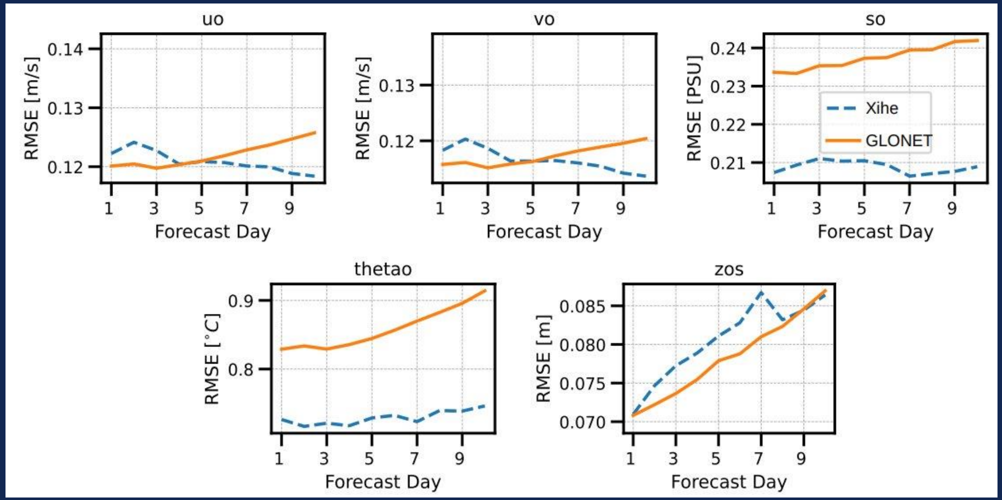

Lellouche, Jean-Michel, et al. "Recent updates to the Copernicus Marine Service global ocean monitoring and forecasting real-time 1/12∘ high-resolution system." Ocean Science 14.5 (2018): 1093-1126.

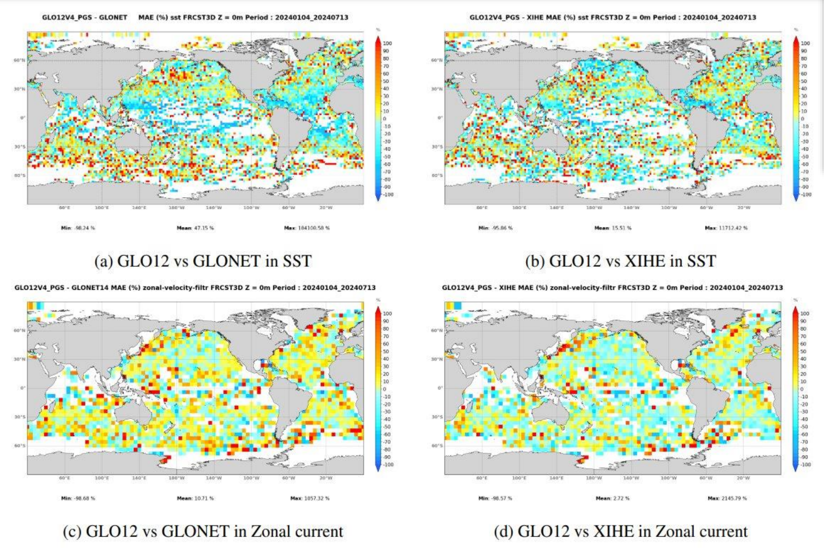
## Hybrid models

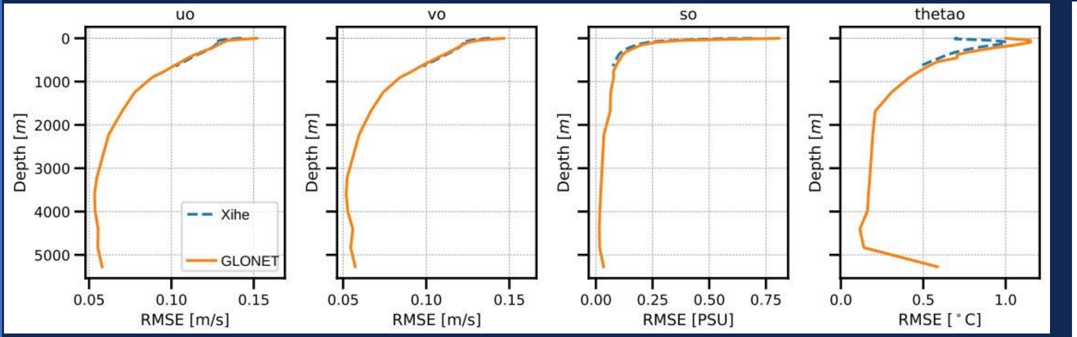
**ANY?**

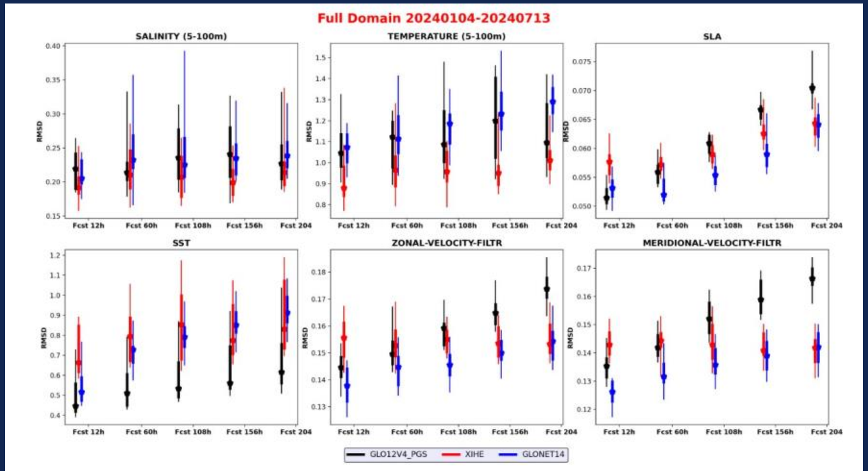
# OceanBench: Evaluation Metrics

## Pointwise





(a) GLO12 vs GLONET in SST
(b) GLO12 vs XIHE in SST
(c) GLO12 vs GLONET in Zonal current
(d) GLO12 vs XIHE in Zonal current



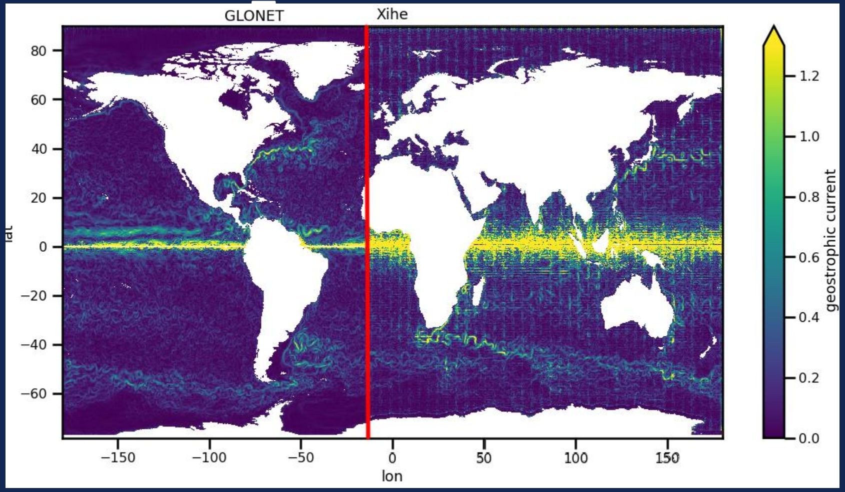



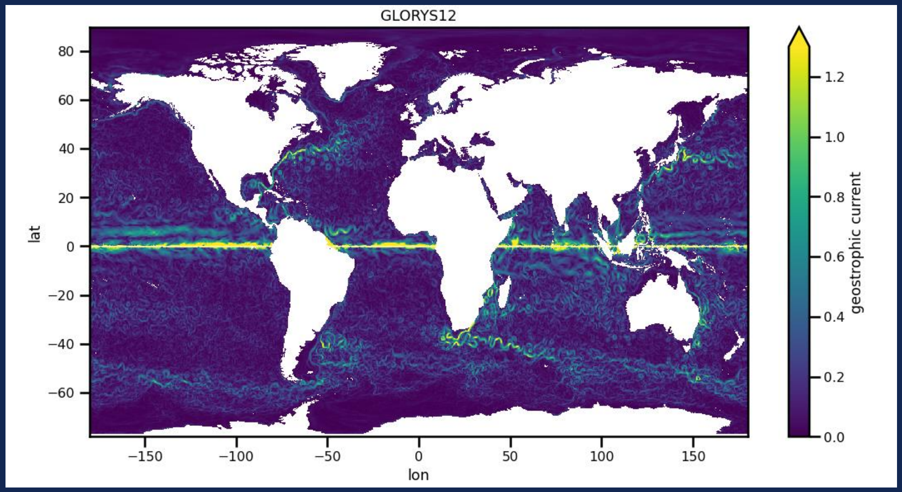

### Evaluation metrics

# OceanBench: Evaluation Metrics

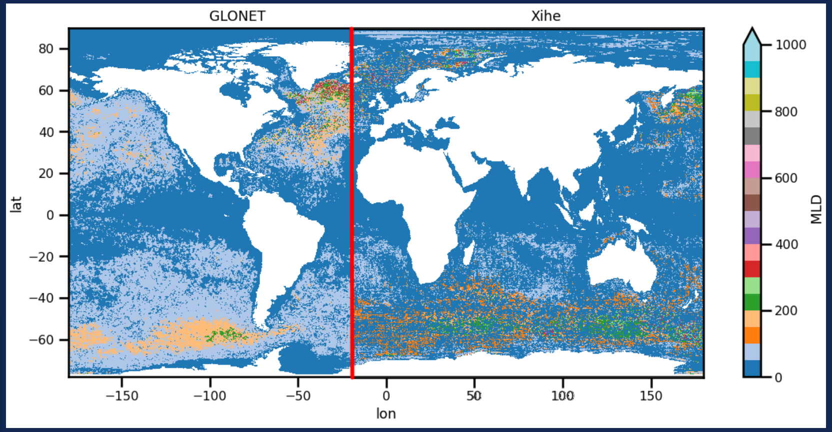
## *Process-based*

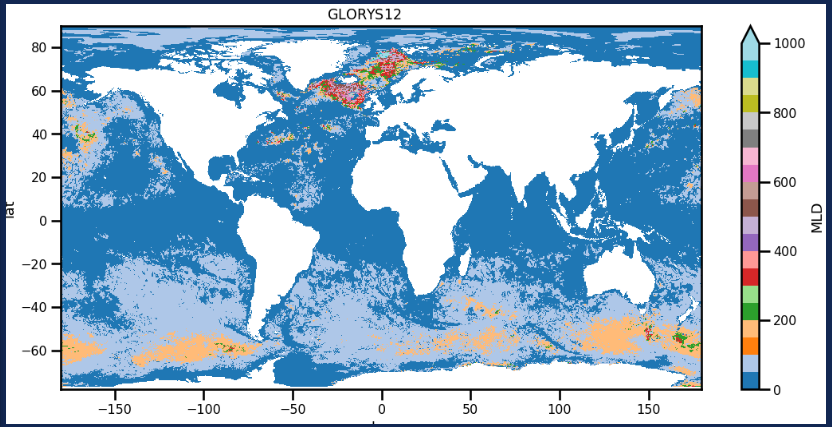
### Geo_currents



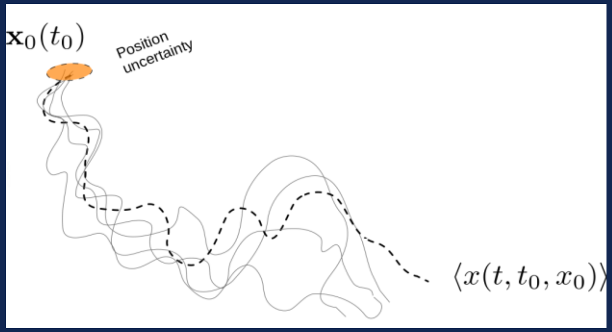

### MLD



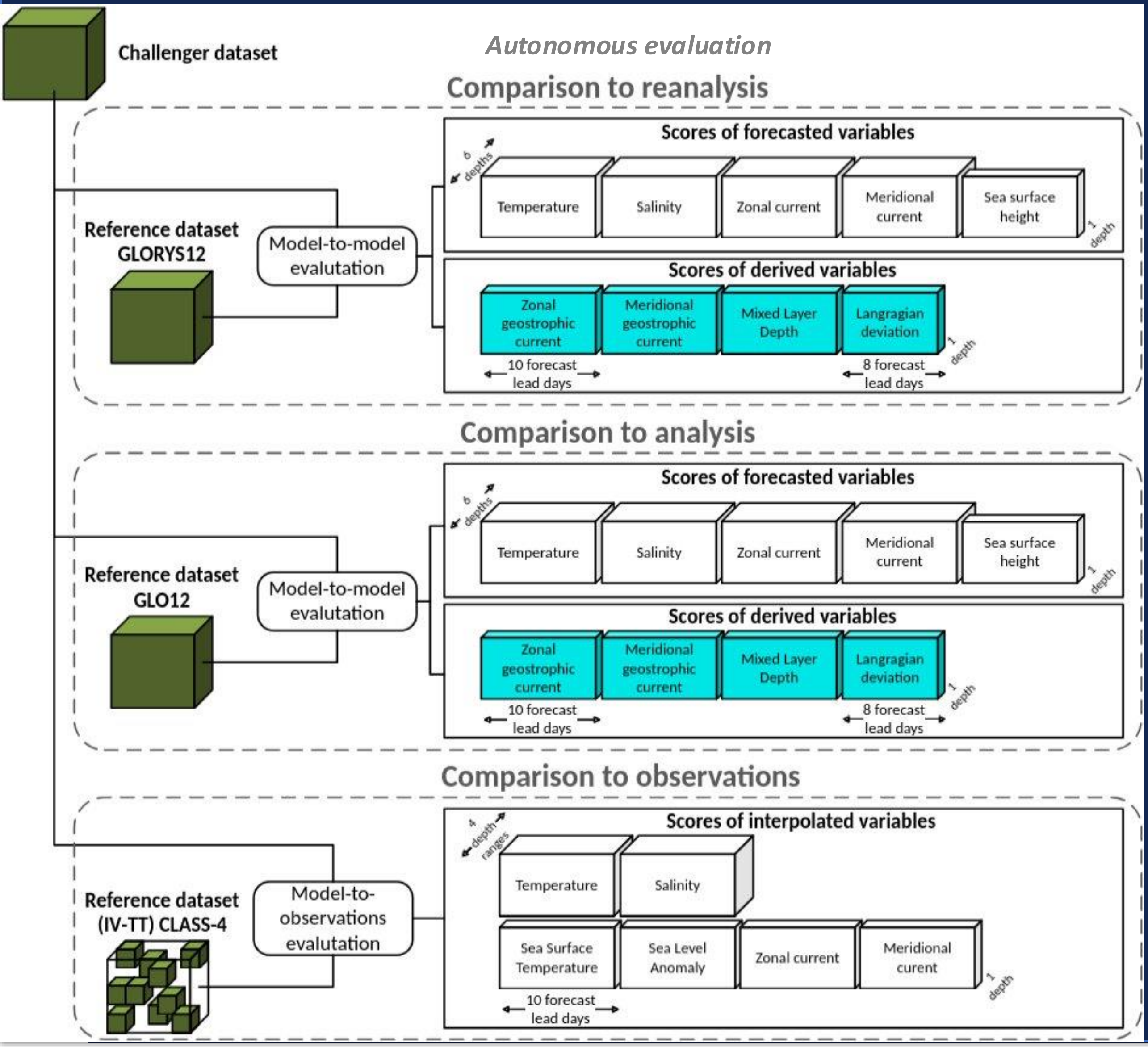




## *Evaluation metrics*

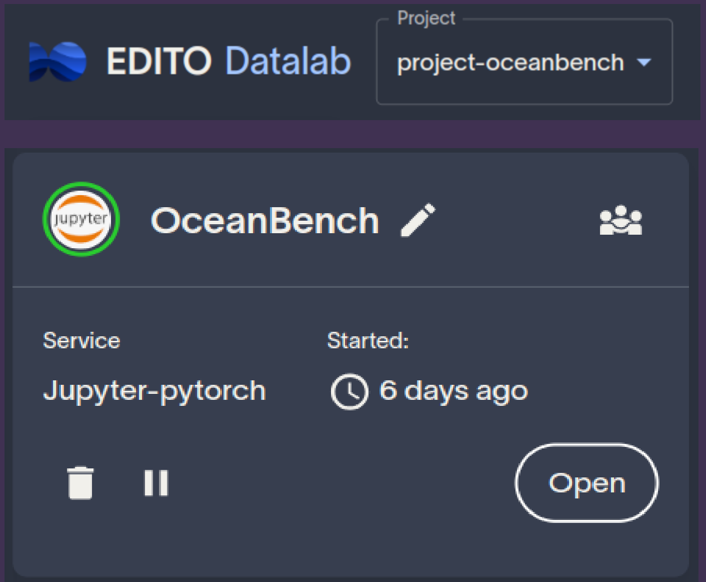
### Lagrangian Drift



# OceanBench: Benchmarking process

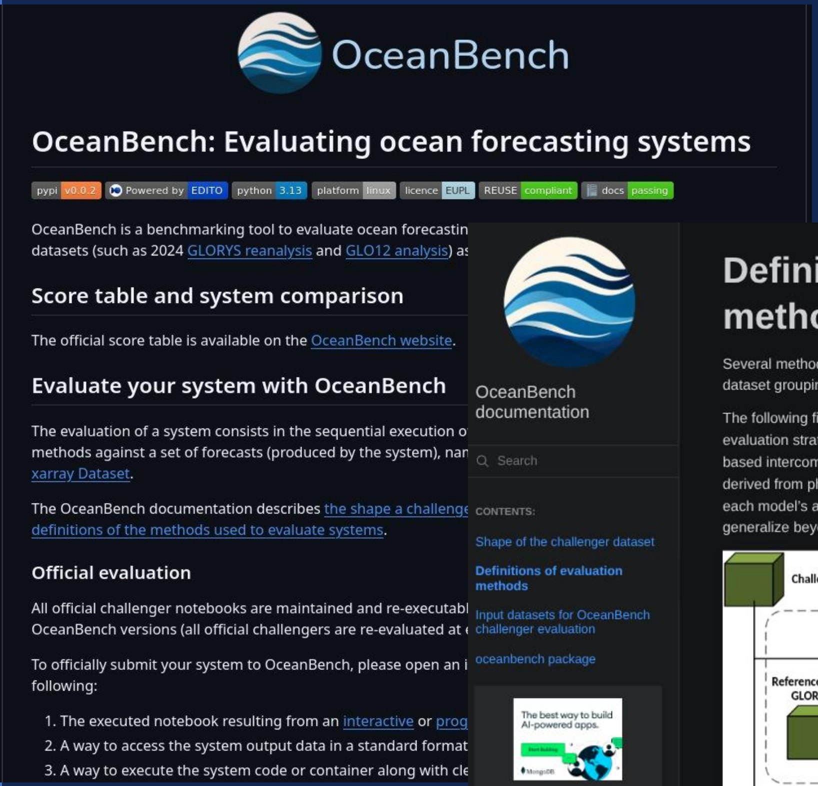



*Evaluation process*

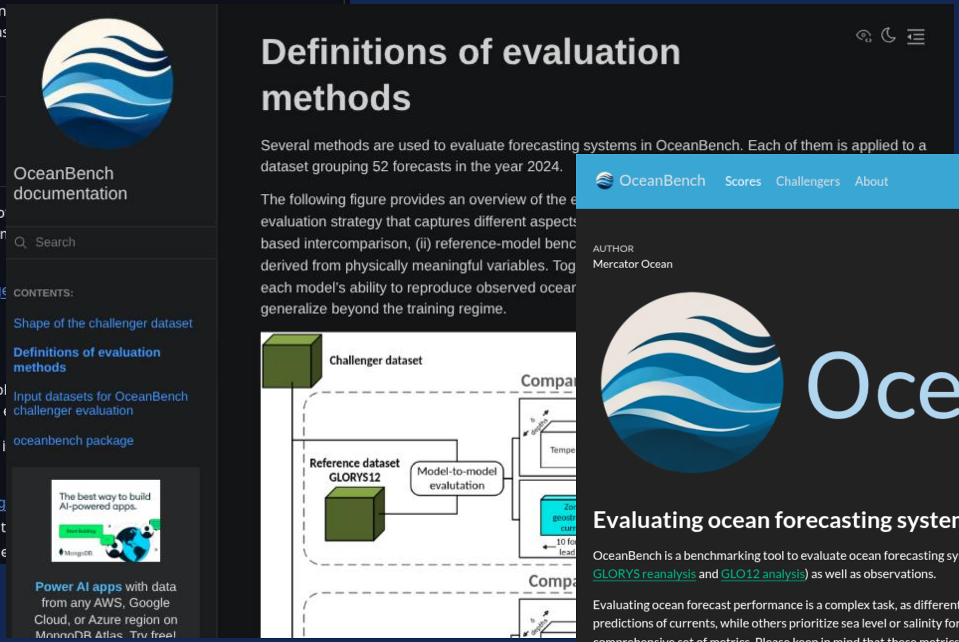


# OceanBench: Project

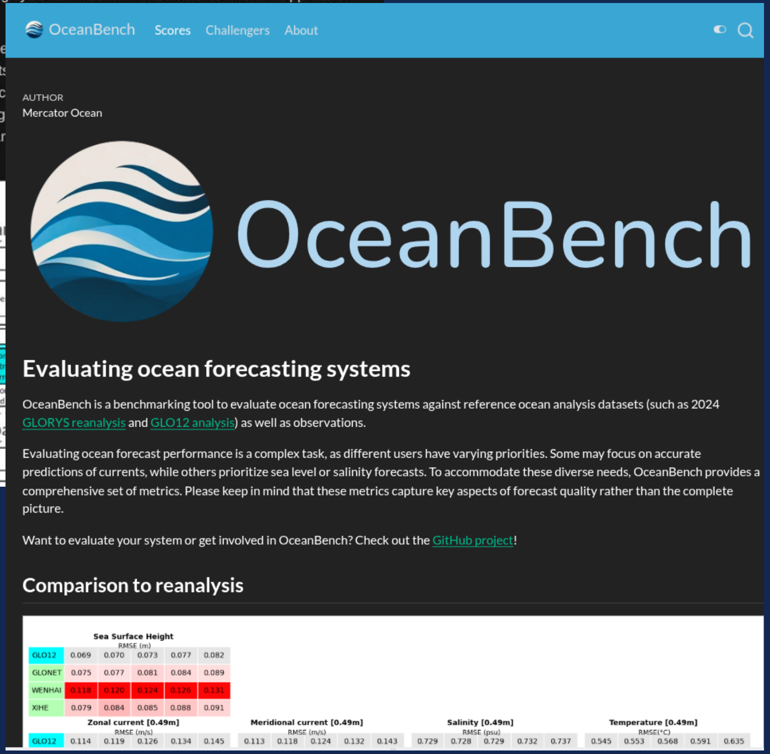
## Code



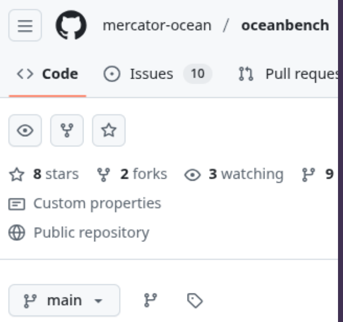

## Documentation




## Website

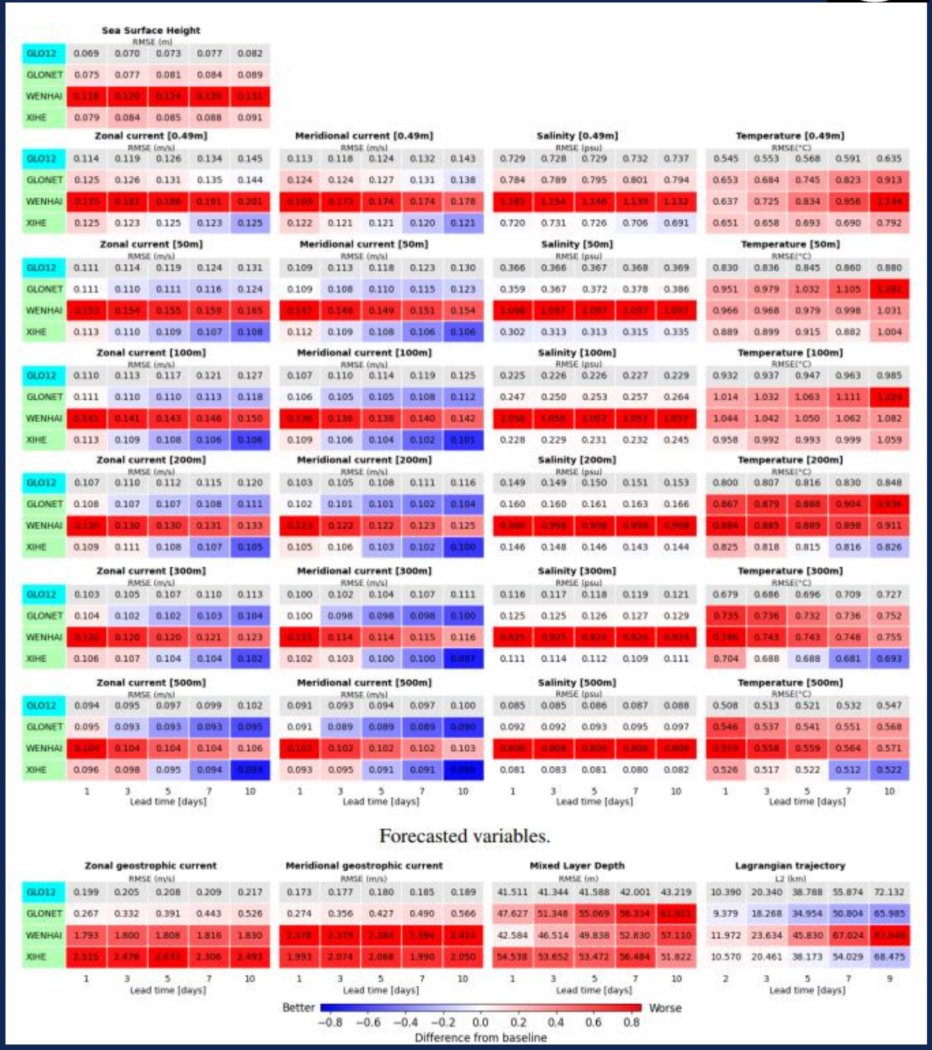



## *Github Project*

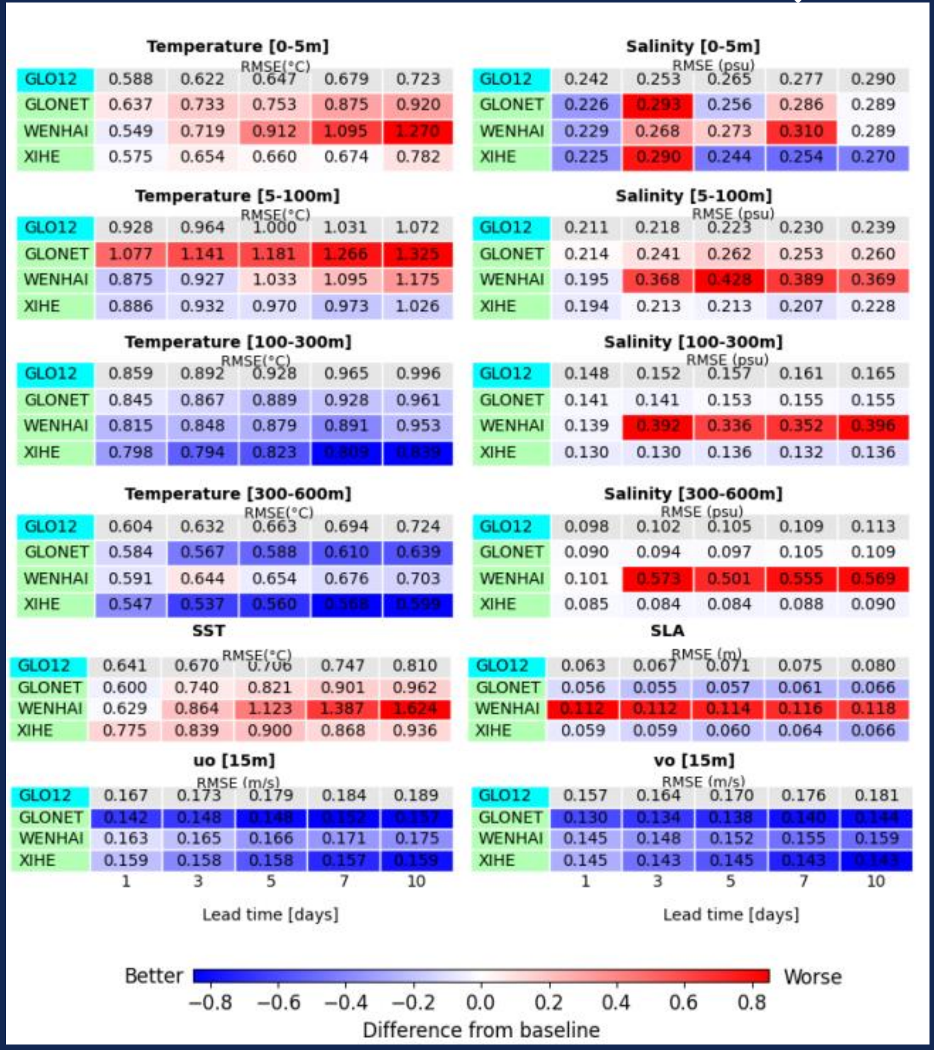


# OceanBench: Headline Scores

## Models-to-Reanalysis



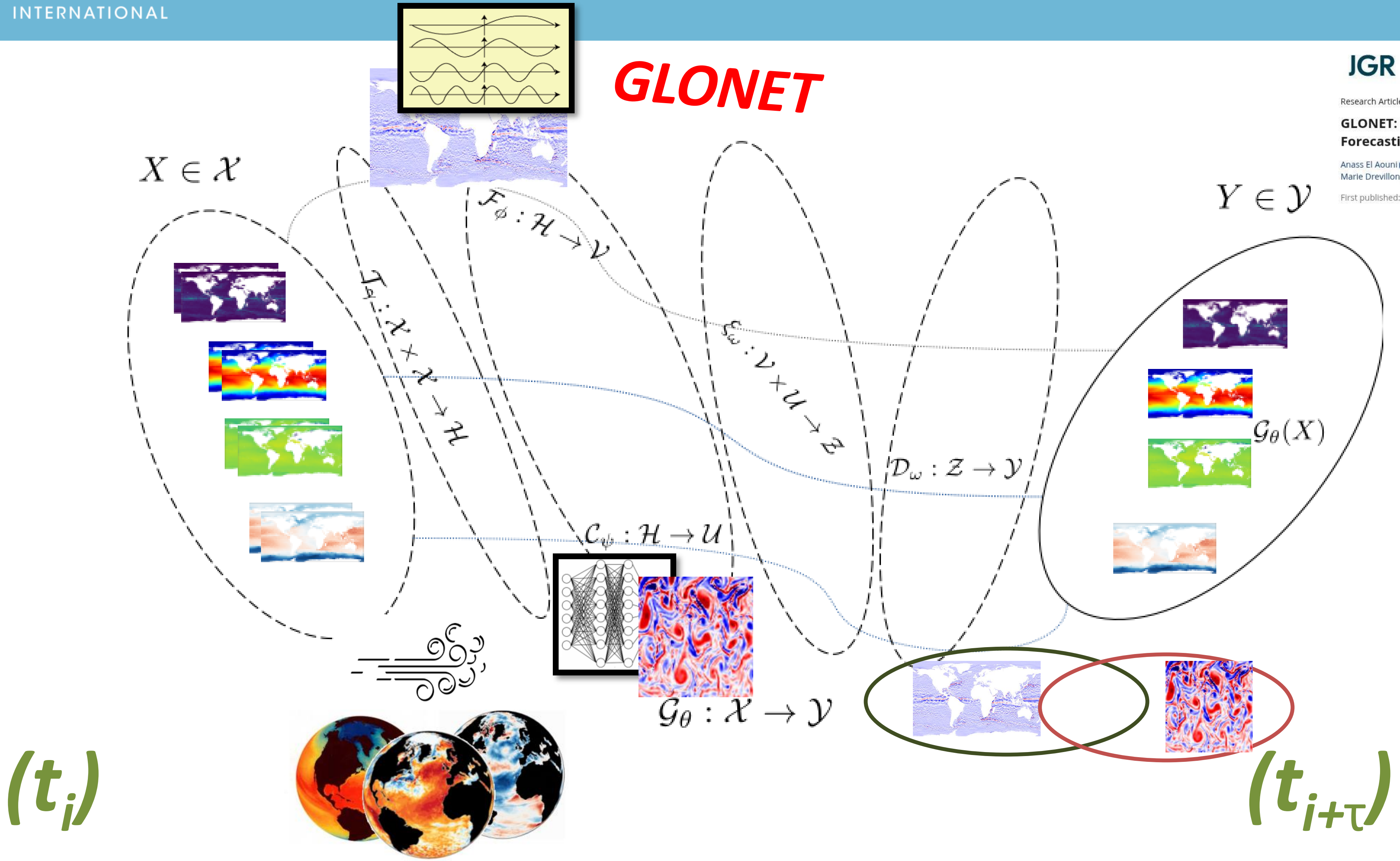

## Models-to-Observation




## Models-to-Analysis

# RESULTS

# GLONET AI Forecasting system




JGR Machine Learning and Computation

Research Article | Open Access

**GLONET: Mercator's End-to-End Neural Global Ocean Forecasting System**

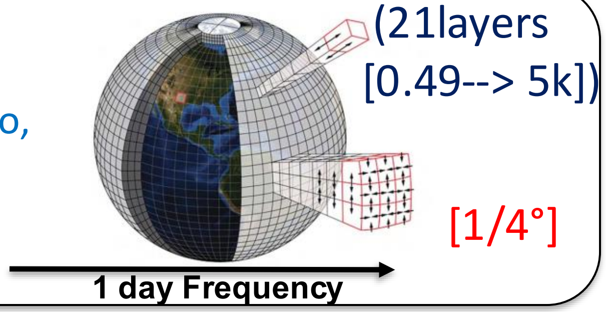
Anass El Aouni, Quentin Gaudel, Charly Regnier, Simon Van Gennip, Olivier Le Galloudec, Marie Drevillon, Yann Drillet, Jean-Michel Lellouche

First published: 16 September 2025 | https://doi.org/10.1029/2025JH000686

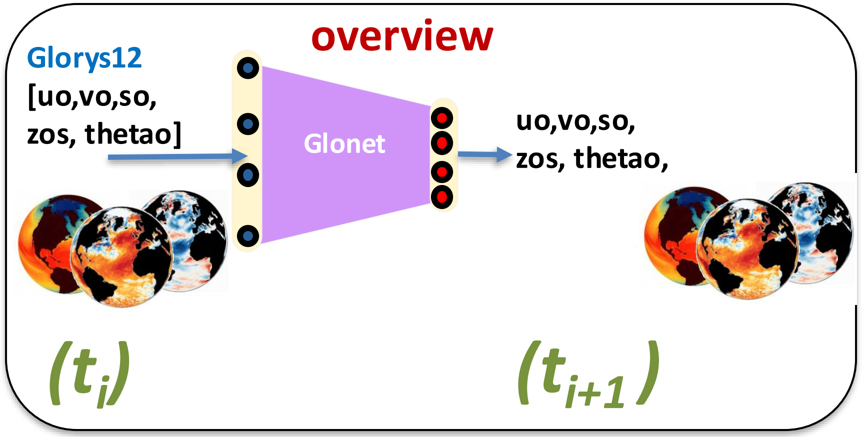
# GLONET AI Forecasting system

- **GLORY12**
  - Training [1993, 2020]
  - Validation [2021]
  - Testing [GLO12]

**Vars:**
zos
[thetao,
uo,vo,
so]

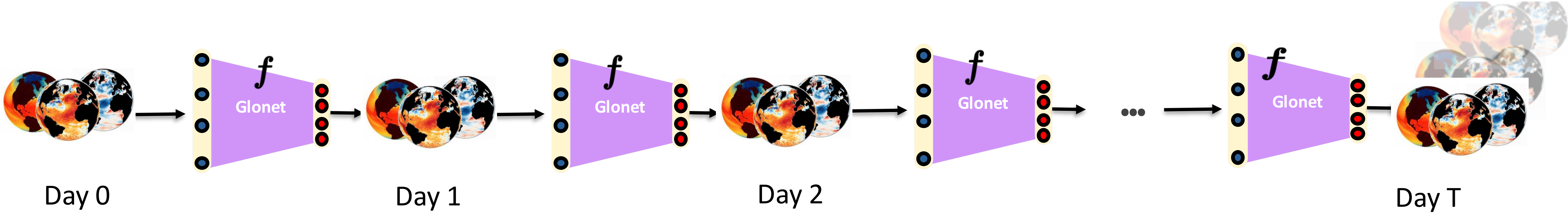



**Glonet [1/4]**
**Configuration**

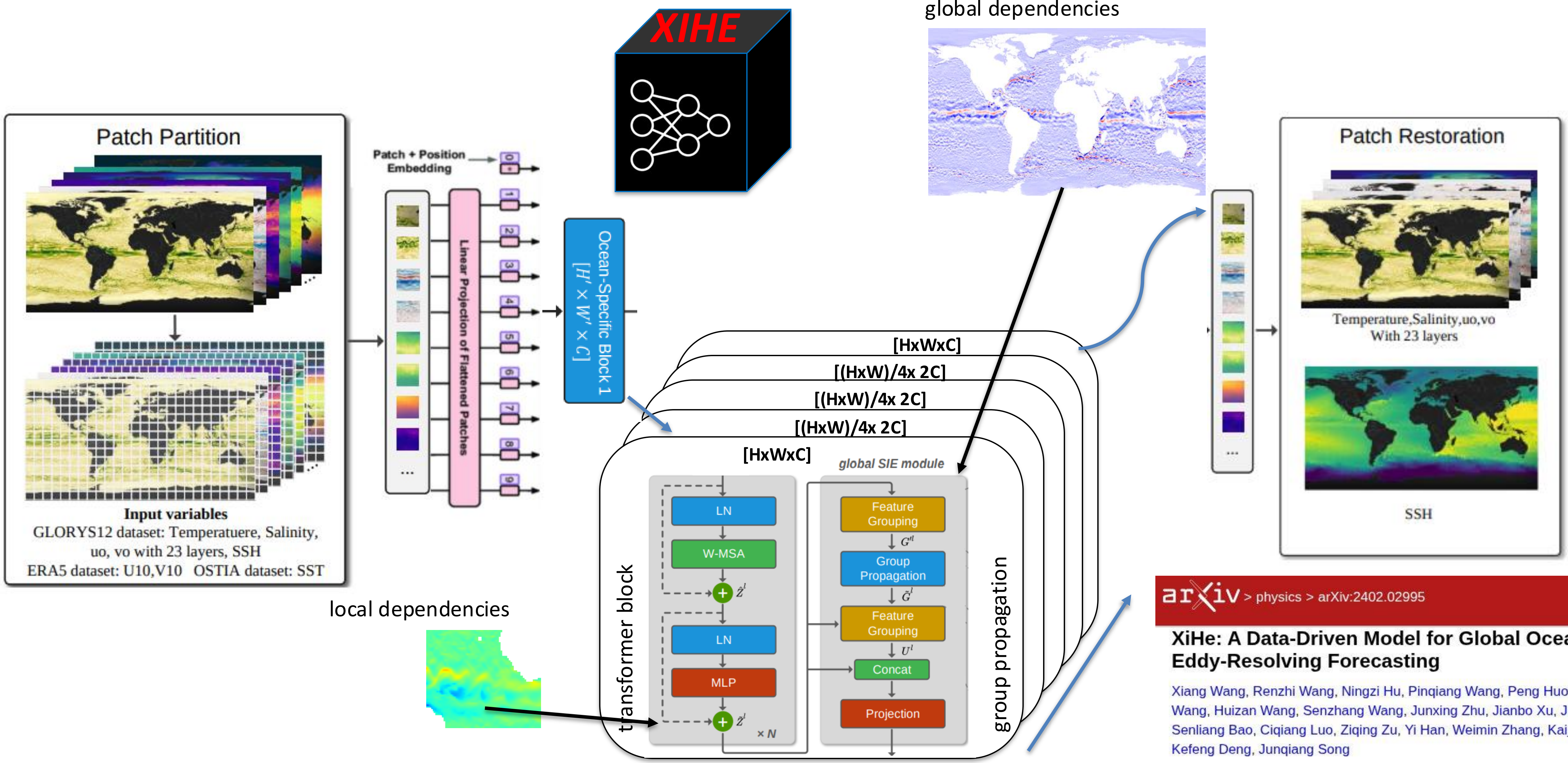



**Training**

- RMSE over one step
- Finetune over 4 steps rollout (accumulated RMSE)



# XiHe AI Forecasting system




arXiv > physics > arXiv:2402.02995

**XiHe: A Data-Driven Model for Global Ocean Eddy-Resolving Forecasting**

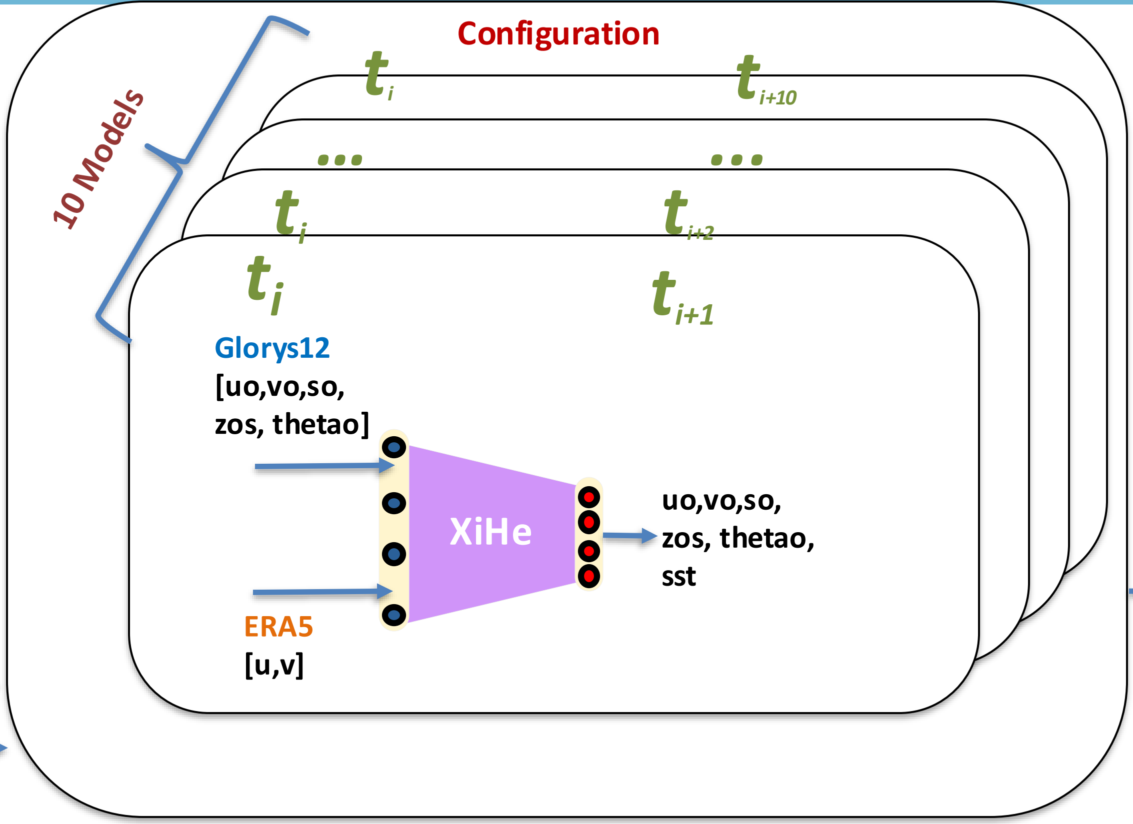
Xiang Wang, Renzhi Wang, Ningzi Hu, Pinqiang Wang, Peng Huo, Guihua Wang, Huizan Wang, Senzhang Wang, Junxing Zhu, Jianbo Xu, Jun Yin, Senliang Bao, Ciqiang Luo, Ziqing Zu, Yi Han, Weimin Zhang, Kaijun Ren, Kefeng Deng, Junqiang Song

# XiHe AI Forecasting system

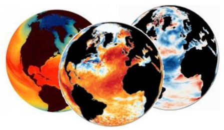
## Dataset

- **GLORY12** [zos][thetao, uo,vo, so]
  (23 layers [0.49--> 643.57m])
    - Training [1993~2017]
    - Validation [2018]
    - Testing [2019~2020]
- **ERA5** (1/4°) ---> (1/12°) [10m wind]
    - Training [1993~2017]
    - Validation [2018]
    - Testing [2019~2020]
- **OSTIA** (1/20°) ---> (1/12°)
    - Training [1993 ~ 2017]

## Training Setup

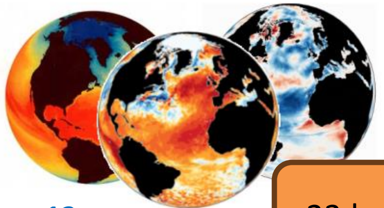




$t_{i+1...}, t_{i+10}$



Xihe
[uo,vo,so,
zos, thetao]

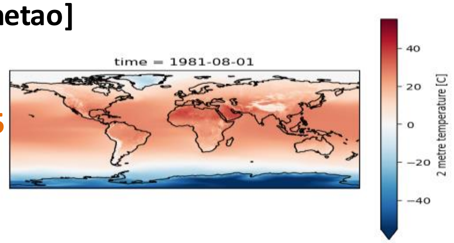
$(t_i)$



Glorys12
[uo,vo,so,
zos, thetao]

23 levels

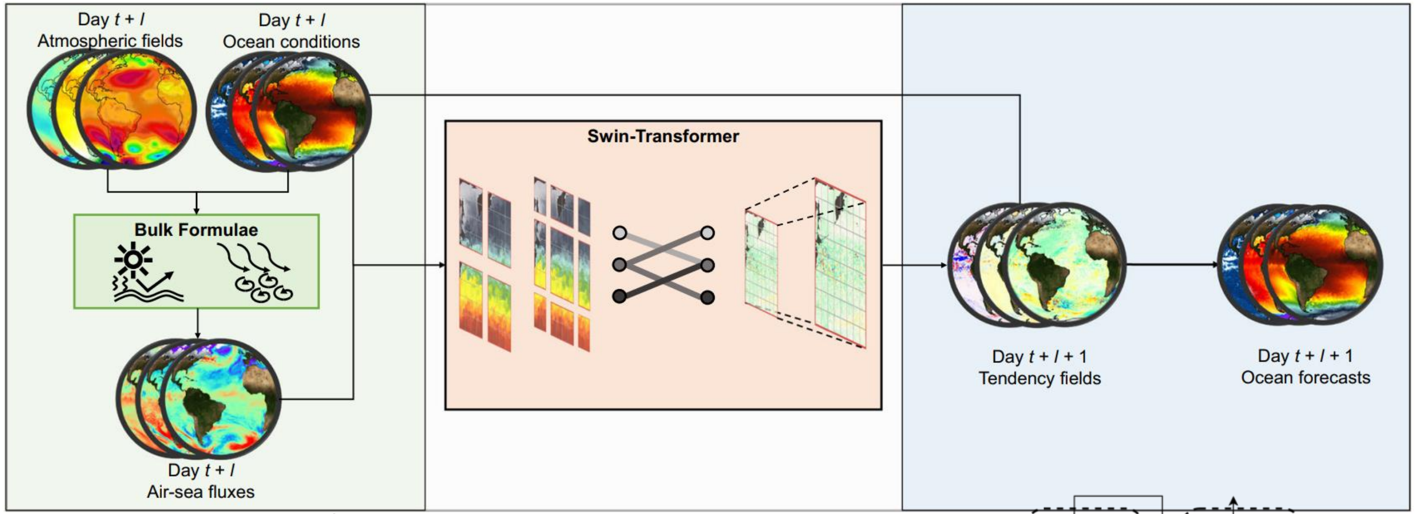
ERA5
[u,v]

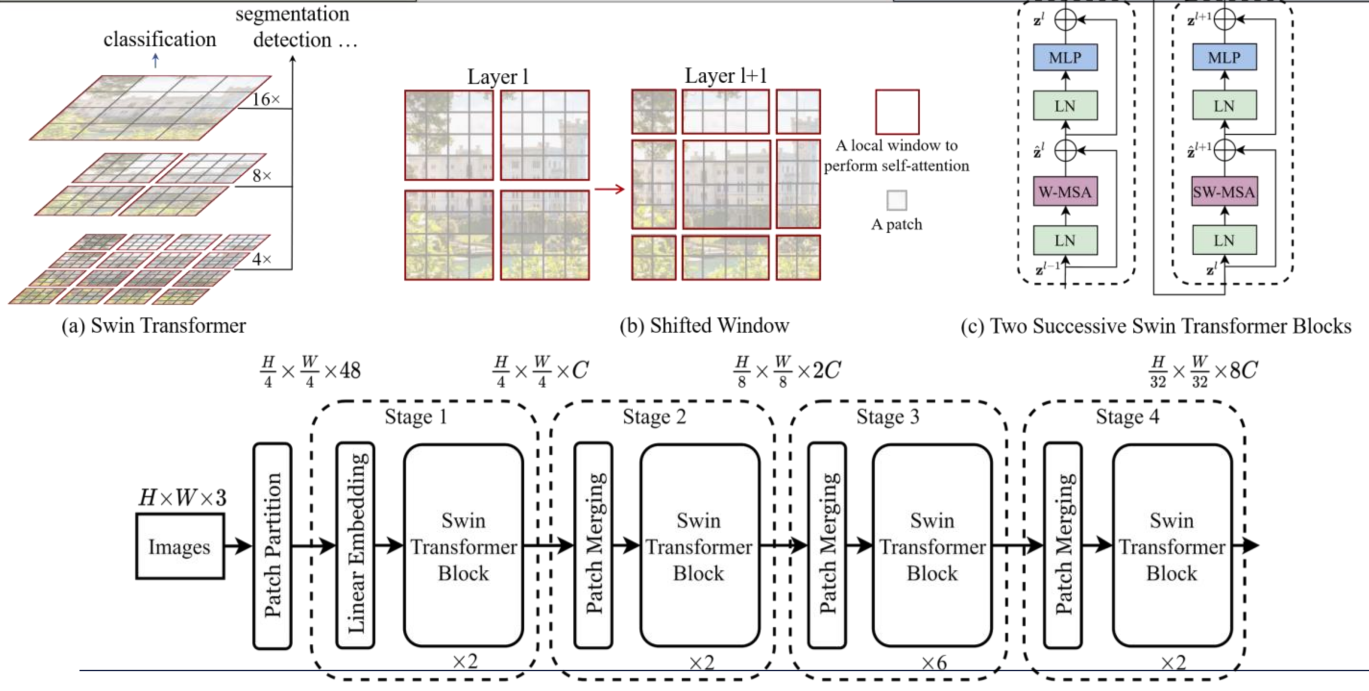



### Training

- RMSE to produce t+1
- Finetune separate checkpoints for t+1, t+2 .. t+10

# Wenhai, AI Global Forecasting system




(a) Swin Transformer (b) Shifted Window (c) Two Successive Swin Transformer Blocks

(d) Architecture

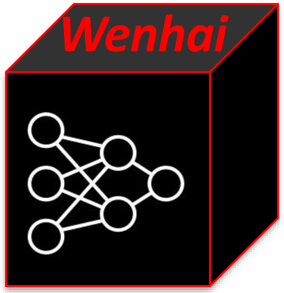

Article | Open access | Published: 06 March 2025


## Forecasting the eddying ocean with a deep neural network


Yingzhe Cui, Ruohan Wu, Xiang Zhang, Ziqi Zhu, Bo Liu, Jun Shi, Junshi Chen, Hailong Liu, Shenghui Zhou, Liang Su, Zhao Jing, Hong An & Lixin Wu

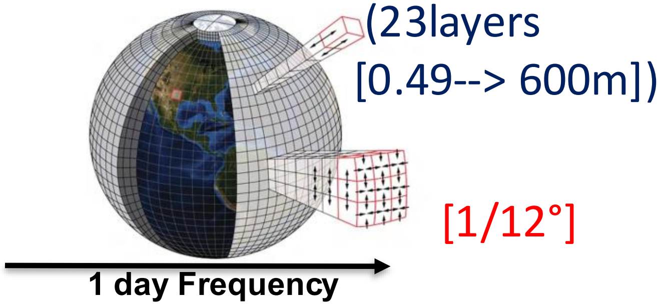


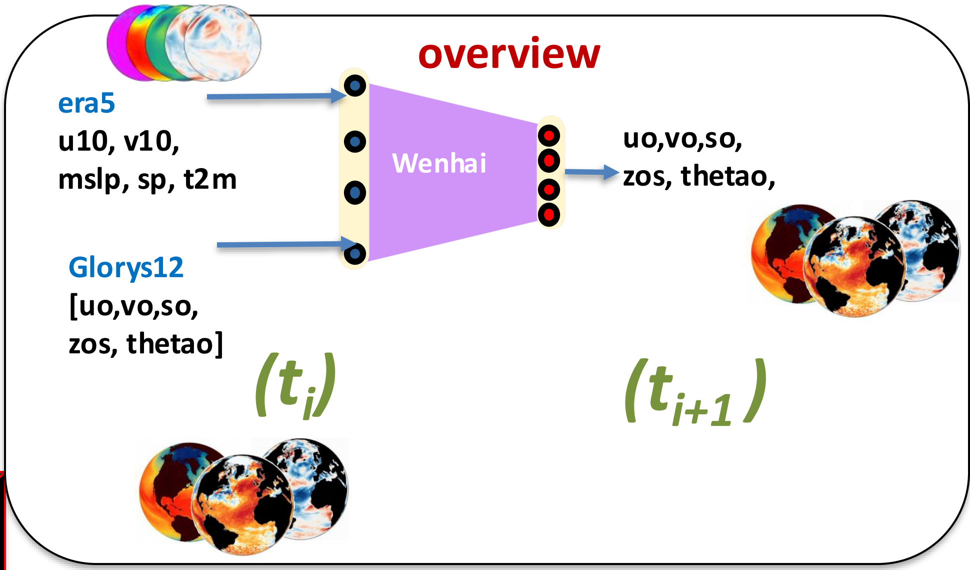
*Nature Communications* **16**, Article number: 2268 (2025) | Cite this article

# Wenhai, AI Global Forecasting system

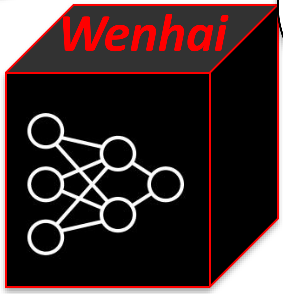
- **GLORY12** [zos][thetao, uo,vo, so]
  - Training [1993, 2020]
- ERA5 [u10, v10, mslp, sp, t2m]
  - Training [1993, 2020]

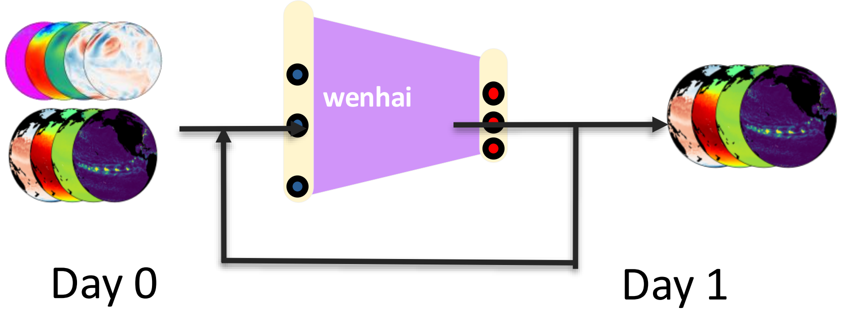


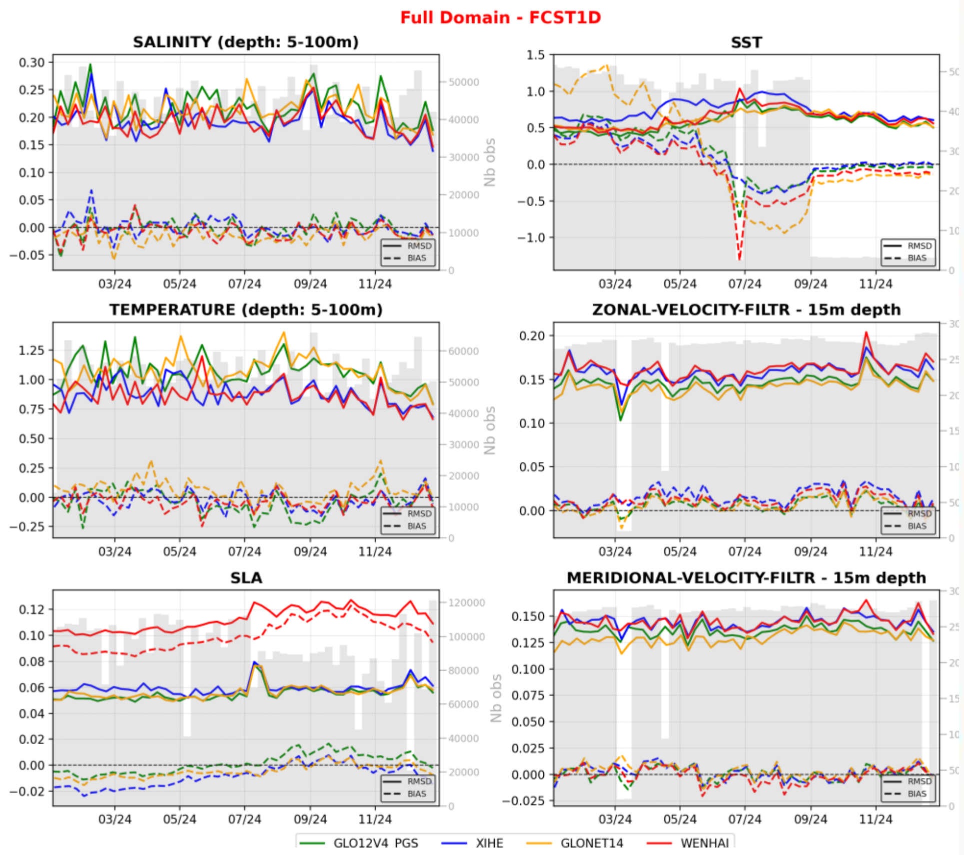

## Training

- Weighted MAE over one step
- Finetune over 5 steps rollout (accumulated)



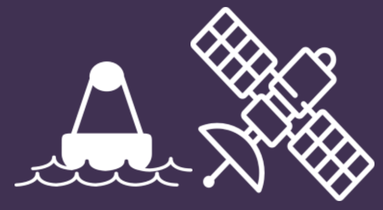
# Model to observations




## Forecasted variables

| Models | Temperature RMSE (°C) sea_water_potential_temperature | | | | | Salinity RMSE (PSU) sea_water_salinity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Lead days* | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 |
| **0-5m** | | | | | | | | | | |
| GLO12 | 0.59 | 0.62 | 0.65 | 0.68 | 0.72 | 0.24 | 0.25 | 0.27 | 0.28 | 0.29 |
| GLONET | 0.64 | 0.73 | 0.75 | 0.88 | 0.92 | 0.23 | 0.29 | 0.26 | 0.29 | 0.29 |
| WenHai | 0.55 | 0.72 | 0.91 | 1.09 | 1.27 | 0.23 | 0.27 | 0.27 | 0.31 | 0.29 |
| XiHe | 0.57 | 0.65 | 0.66 | 0.67 | 0.78 | 0.23 | 0.29 | 0.24 | 0.25 | 0.27 |
| **5-100m** | | | | | | | | | | |
| GLO12 | 0.93 | 0.96 | 1.00 | 1.03 | 1.07 | 0.21 | 0.22 | 0.22 | 0.23 | 0.24 |
| GLONET | 1.08 | 1.14 | 1.18 | 1.27 | 1.32 | 0.21 | 0.24 | 0.26 | 0.25 | 0.26 |
| WenHai | 0.88 | 0.93 | 1.03 | 1.09 | 1.18 | 0.20 | 0.37 | 0.43 | 0.39 | 0.37 |
| XiHe | 0.89 | 0.93 | 0.97 | 0.97 | 1.03 | 0.19 | 0.21 | 0.21 | 0.21 | 0.23 |
| **100-300m** | | | | | | | | | | |
| GLO12 | 0.86 | 0.89 | 0.93 | 0.96 | 1.00 | 0.15 | 0.15 | 0.16 | 0.16 | 0.17 |
| GLONET | 0.84 | 0.87 | 0.89 | 0.93 | 0.96 | 0.14 | 0.14 | 0.15 | 0.15 | 0.15 |
| WenHai | 0.81 | 0.85 | 0.88 | 0.89 | 0.95 | 0.14 | 0.39 | 0.34 | 0.35 | 0.40 |
| XiHe | 0.80 | 0.79 | 0.82 | 0.81 | 0.84 | 0.13 | 0.13 | 0.14 | 0.13 | 0.14 |
| **300-600m** | | | | | | | | | | |
| GLO12 | 0.60 | 0.63 | 0.66 | 0.69 | 0.72 | 0.10 | 0.10 | 0.10 | 0.11 | 0.11 |
| GLONET | 0.58 | 0.57 | 0.59 | 0.61 | 0.64 | 0.09 | 0.09 | 0.10 | 0.10 | 0.11 |
| WenHai | 0.59 | 0.64 | 0.65 | 0.68 | 0.70 | 0.10 | 0.57 | 0.50 | 0.56 | 0.57 |
| XiHe | 0.55 | 0.54 | 0.56 | 0.57 | 0.60 | 0.09 | 0.08 | 0.08 | 0.09 | 0.09 |

*reference*



| Models | Temperature RMSE (°C) sea_surface_temperature | | | | | Sea Surface Height RMSE (m) sea_surface_height_above_geoid | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Lead days* | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 |
| GLO12 | 0.64 | 0.67 | 0.71 | 0.75 | 0.81 | 0.06 | 0.07 | 0.07 | 0.07 | 0.08 |
| GLONET | 0.60 | 0.74 | 0.82 | 0.90 | 0.96 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 |
| WenHai | 0.63 | 0.86 | 1.12 | 1.39 | 1.62 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 |
| XiHe | 0.78 | 0.84 | 0.90 | 0.87 | 0.94 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 |

| Models | Zonal Current RMSE (m/s) eastward_sea_water_velocity | | | | | Meridional Current RMSE (m/s) northward_sea_water_velocity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Lead days* | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 |
| GLO12 | 0.17 | 0.17 | 0.18 | 0.18 | 0.19 | 0.16 | 0.16 | 0.17 | 0.18 | 0.18 |
| GLONET | 0.14 | 0.15 | 0.15 | 0.15 | 0.16 | 0.13 | 0.13 | 0.14 | 0.14 | 0.14 |
| WenHai | 0.16 | 0.17 | 0.17 | 0.17 | 0.17 | 0.14 | 0.15 | 0.15 | 0.15 | 0.16 |
| XiHe | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |

# Model to Reanalysis

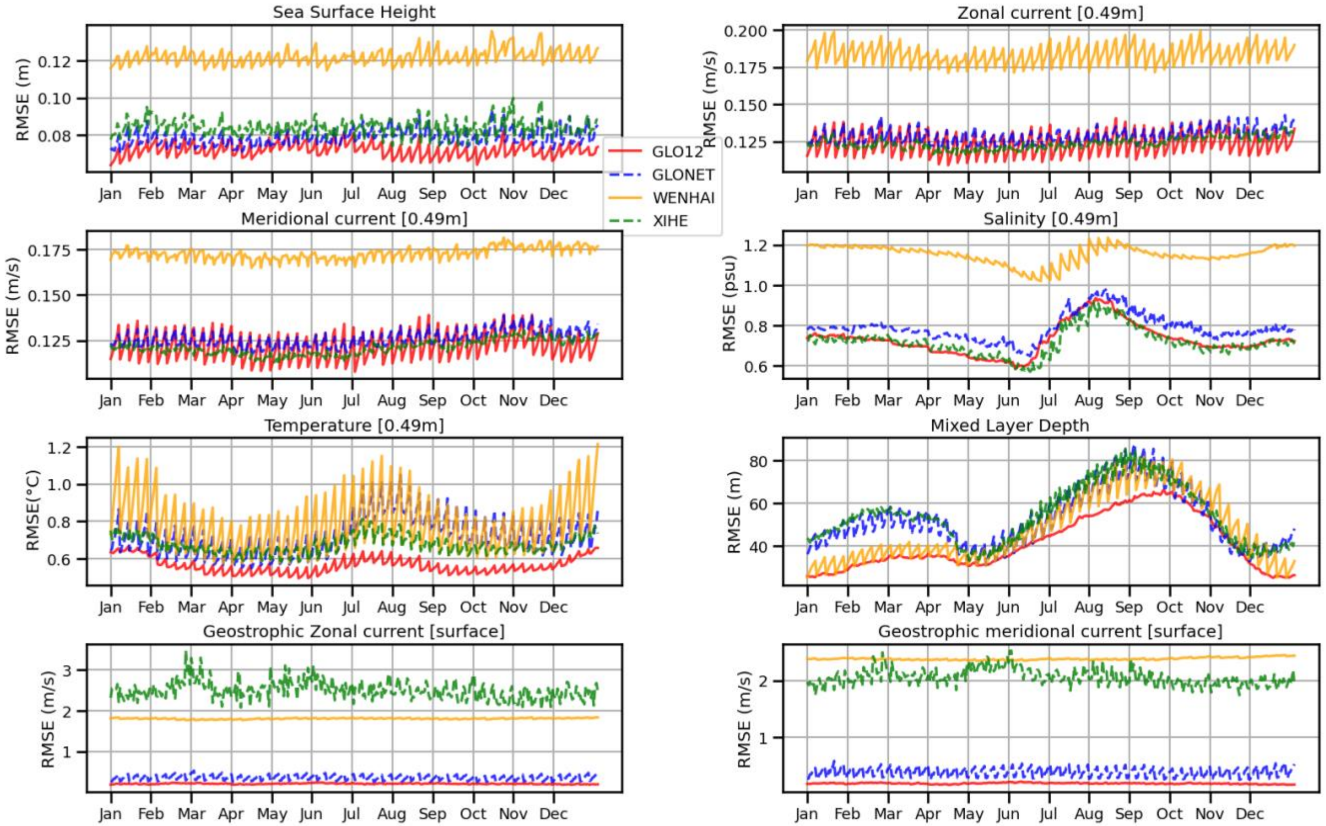
vs GLORYS12

## Forecasted variables

| Models | Temperature RMSE (°C) sea_water_potential_temperature | | | | | Salinity RMSE (PSU) sea_water_salinity | | | | | Zonal Current RMSE (m/s) eastward_sea_water_velocity | | | | | Meridional Current RMSE (m/s) northward_sea_water_velocity | | | | | Sea Surface Height RMSE (m) sea_surface_height_above_geoid | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lead days | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 |
| **Surface** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.55 | 0.55 | 0.57 | 0.59 | 0.64 | 0.73 | 0.73 | 0.73 | 0.73 | 0.74 | 0.11 | 0.12 | 0.13 | 0.13 | 0.14 | 0.11 | 0.12 | 0.12 | 0.13 | 0.14 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 |
| GLONET | 0.65 | 0.68 | 0.74 | 0.82 | 0.91 | 0.78 | 0.79 | 0.80 | 0.80 | 0.79 | 0.13 | 0.13 | 0.13 | 0.14 | 0.14 | 0.12 | 0.12 | 0.13 | 0.13 | 0.14 | 0.07 | 0.08 | 0.08 | 0.08 | 0.09 |
| WenHai | 0.64 | 0.72 | 0.83 | 0.96 | 1.14 | 1.17 | 1.15 | 1.15 | 1.14 | 1.13 | 0.17 | 0.18 | 0.19 | 0.19 | 0.20 | 0.17 | 0.17 | 0.17 | 0.17 | 0.18 | 0.12 | 0.12 | 0.12 | 0.13 | 0.13 |
| XiHe | 0.65 | 0.66 | 0.69 | 0.69 | 0.79 | 0.72 | 0.73 | 0.73 | 0.71 | 0.69 | 0.13 | 0.12 | 0.13 | 0.12 | 0.13 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 |
| **50m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.83 | 0.84 | 0.84 | 0.86 | 0.88 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | | | | | |
| GLONET | 0.95 | 0.98 | 1.03 | 1.10 | 1.26 | 0.36 | 0.37 | 0.37 | 0.38 | 0.39 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | | | | | |
| WenHai | 0.97 | 0.97 | 0.98 | 1.00 | 1.03 | 1.10 | 1.10 | 1.10 | 1.10 | 1.10 | 0.15 | 0.15 | 0.15 | 0.16 | 0.17 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | | | | | |
| XiHe | 0.89 | 0.90 | 0.92 | 0.88 | 1.00 | 0.30 | 0.31 | 0.31 | 0.32 | 0.34 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | | | | | |
| **100m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.93 | 0.94 | 0.95 | 0.96 | 0.98 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.11 | 0.11 | 0.11 | 0.12 | 0.13 | | | | | |
| GLONET | 1.01 | 1.03 | 1.06 | 1.11 | 1.22 | 0.25 | 0.25 | 0.25 | 0.26 | 0.26 | 0.11 | 0.11 | 0.11 | 0.11 | 0.12 | 0.11 | 0.10 | 0.10 | 0.11 | 0.11 | | | | | |
| WenHai | 1.04 | 1.04 | 1.05 | 1.06 | 1.08 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | | | | | |
| XiHe | 0.96 | 0.99 | 0.99 | 1.00 | 1.06 | 0.23 | 0.23 | 0.23 | 0.23 | 0.24 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | | | | | |
| **200m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.80 | 0.81 | 0.82 | 0.83 | 0.85 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.10 | 0.10 | 0.11 | 0.11 | 0.12 | | | | | |
| GLONET | 0.87 | 0.88 | 0.89 | 0.90 | 0.94 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | | | | | |
| WenHai | 0.88 | 0.89 | 0.89 | 0.90 | 0.91 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.12 | 0.12 | 0.12 | 0.12 | 0.13 | | | | | |
| XiHe | 0.82 | 0.82 | 0.81 | 0.82 | 0.83 | 0.15 | 0.15 | 0.15 | 0.14 | 0.14 | 0.11 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.11 | 0.10 | 0.10 | 0.10 | | | | | |
| **300m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.68 | 0.69 | 0.70 | 0.71 | 0.73 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.10 | 0.10 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | 0.11 | 0.11 | | | | | |
| GLONET | 0.73 | 0.74 | 0.73 | 0.74 | 0.75 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | | | | | |
| WenHai | 0.75 | 0.74 | 0.74 | 0.75 | 0.76 | 0.93 | 0.93 | 0.92 | 0.92 | 0.92 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.11 | 0.11 | 0.12 | 0.12 | | | | | |
| XiHe | 0.70 | 0.69 | 0.69 | 0.68 | 0.69 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | | | | | |
| **500m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.51 | 0.51 | 0.52 | 0.53 | 0.55 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 | 0.09 | 0.09 | 0.09 | 0.10 | 0.10 | | | | | |
| GLONET | 0.55 | 0.54 | 0.54 | 0.55 | 0.57 | 0.09 | 0.09 | 0.09 | 0.10 | 0.10 | 0.10 | 0.09 | 0.09 | 0.09 | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | | | | | |
| WenHai | 0.56 | 0.56 | 0.56 | 0.56 | 0.57 | 0.81 | 0.81 | 0.81 | 0.81 | 0.81 | 0.10 | 0.10 | 0.10 | 0.10 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | | | | | |
| XiHe | 0.53 | 0.52 | 0.52 | 0.51 | 0.52 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.10 | 0.10 | 0.10 | 0.09 | 0.09 | 0.09 | 0.10 | 0.09 | 0.09 | 0.09 | | | | | |

## Physically consistent diagnostic variables

| Models | Mixed Layer Depth RMSE (m) ocean_mixed_layer_thickness | | | | | Meridional Geostrophic Current RMSE (m/s) geostrophic_northward_sea_water_velocity | | | | | Zonal Geostrophic Current RMSE (m/s) geostrophic_eastward_sea_water_velocity | | | | | Surface Lagrangian Trajectory Deviation (km) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lead days | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 | 2 | 3 | 5 | 7 | 9 |
| GLO12 | 41.51 | 41.34 | 41.59 | 42.00 | 43.22 | 0.17 | 0.18 | 0.18 | 0.18 | 0.19 | 0.20 | 0.20 | 0.21 | 0.21 | 0.22 | 10.39 | 20.34 | 38.79 | 55.87 | 72.13 |
| GLONET | 47.63 | 51.35 | 55.07 | 58.33 | 61.92 | 0.27 | 0.36 | 0.43 | 0.49 | 0.57 | 0.27 | 0.33 | 0.39 | 0.44 | 0.53 | 9.38 | 18.27 | 34.95 | 50.80 | 65.98 |
| WenHai | 42.58 | 46.51 | 49.84 | 52.83 | 57.11 | 2.38 | 2.38 | 2.38 | 2.39 | 2.41 | 1.79 | 1.80 | 1.81 | 1.82 | 1.83 | 11.97 | 23.63 | 45.83 | 67.02 | 87.65 |
| XiHe | 54.54 | 53.65 | 53.47 | 56.48 | 51.82 | 1.99 | 2.07 | 2.07 | 1.99 | 2.05 | 2.52 | 2.48 | 2.67 | 2.31 | 2.49 | 10.57 | 20.46 | 38.17 | 54.03 | 68.47 |

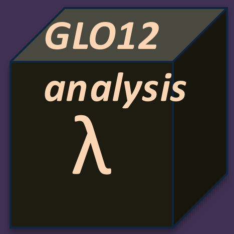


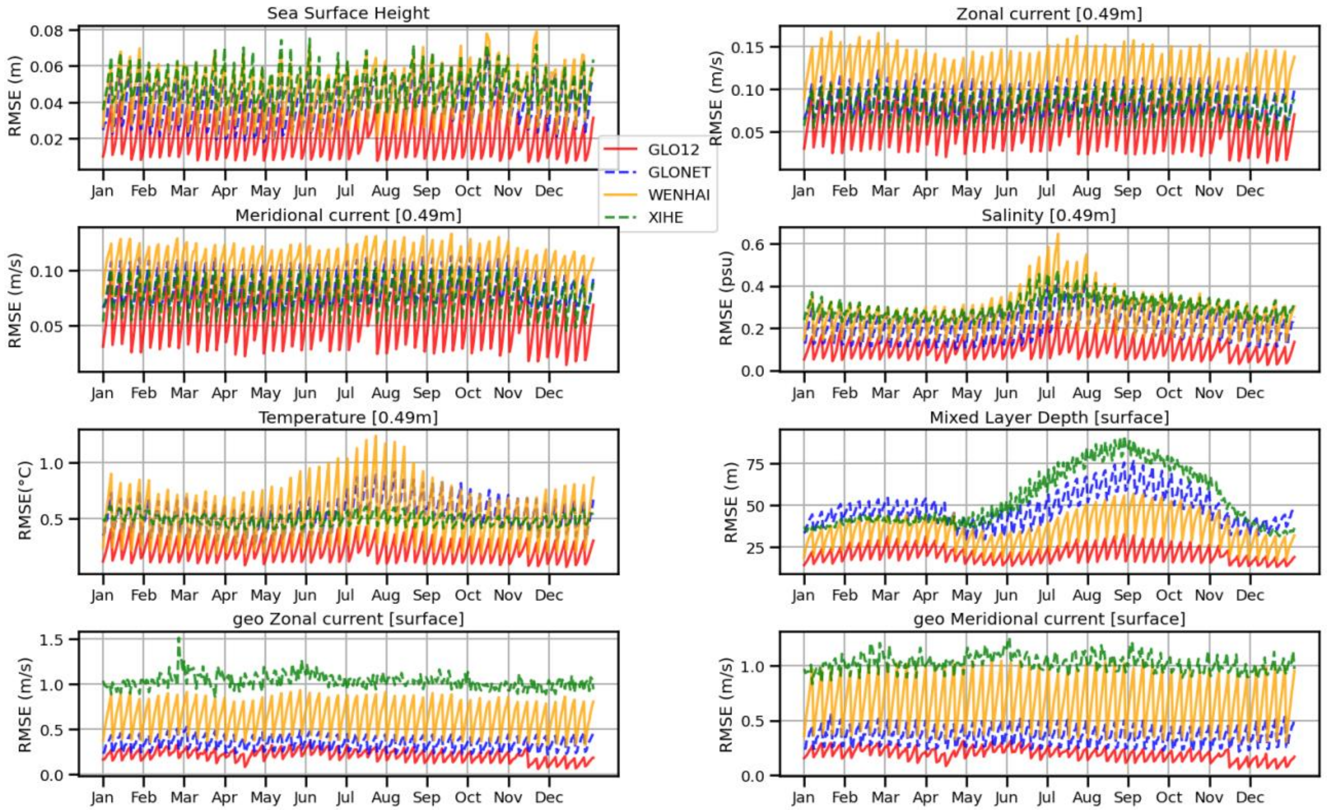
# Model to Analysis

## Forecasted variables

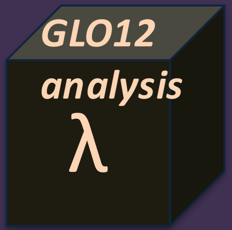
| Models | Temperature RMSE (°C) sea_water_potential_temperature | | | | | Salinity RMSE (PSU) sea_water_salinity | | | | | Zonal Current RMSE (m/s) eastward_sea_water_velocity | | | | | Meridional Current RMSE (m/s) northward_sea_water_velocity | | | | | Sea Surface Height RMSE (m) sea_surface_height_above_geoid | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lead days* | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 | 1 | 3 | 5 | 7 | 10 |
| **Surface** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.11 | 0.17 | 0.26 | 0.35 | 0.47 | 0.05 | 0.08 | 0.12 | 0.17 | 0.22 | 0.03 | 0.04 | 0.07 | 0.09 | 0.12 | 0.03 | 0.04 | 0.07 | 0.09 | 0.12 | 0.01 | 0.01 | 0.02 | 0.04 | 0.05 |
| GLONET | 0.39 | 0.48 | 0.60 | 0.71 | 0.83 | 0.14 | 0.20 | 0.26 | 0.30 | 0.35 | 0.07 | 0.07 | 0.09 | 0.11 | 0.13 | 0.07 | 0.07 | 0.09 | 0.11 | 0.13 | 0.03 | 0.03 | 0.05 | 0.05 | 0.07 |
| WenHai | 0.22 | 0.45 | 0.65 | 0.84 | 1.10 | 0.16 | 0.25 | 0.31 | 0.36 | 0.42 | 0.08 | 0.11 | 0.13 | 0.15 | 0.17 | 0.07 | 0.10 | 0.11 | 0.12 | 0.14 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 |
| XiHe | 0.44 | 0.45 | 0.52 | 0.55 | 0.64 | 0.25 | 0.28 | 0.30 | 0.34 | 0.40 | 0.06 | 0.07 | 0.09 | 0.10 | 0.11 | 0.05 | 0.07 | 0.09 | 0.10 | 0.11 | 0.04 | 0.05 | 0.05 | 0.06 | 0.06 |
| **50m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.16 | 0.22 | 0.32 | 0.44 | 0.55 | 0.03 | 0.05 | 0.07 | 0.09 | 0.12 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.03 | 0.04 | 0.06 | 0.08 | 0.10 | | | | | |
| GLONET | 0.70 | 0.75 | 0.84 | 0.95 | 1.13 | 0.10 | 0.14 | 0.16 | 0.18 | 0.20 | 0.05 | 0.06 | 0.07 | 0.08 | 0.11 | 0.05 | 0.06 | 0.07 | 0.08 | 0.10 | | | | | |
| WenHai | 0.23 | 0.37 | 0.49 | 0.60 | 0.72 | 0.05 | 0.08 | 0.10 | 0.12 | 0.14 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.04 | 0.06 | 0.07 | 0.09 | 0.11 | | | | | |
| XiHe | 0.50 | 0.53 | 0.60 | 0.63 | 0.74 | 0.11 | 0.11 | 0.12 | 0.13 | 0.13 | 0.04 | 0.05 | 0.07 | 0.08 | 0.09 | 0.04 | 0.05 | 0.07 | 0.08 | 0.09 | | | | | |
| **100m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.18 | 0.24 | 0.34 | 0.46 | 0.58 | 0.03 | 0.04 | 0.06 | 0.07 | 0.10 | 0.02 | 0.03 | 0.05 | 0.07 | 0.09 | 0.02 | 0.03 | 0.05 | 0.07 | 0.09 | | | | | |
| GLONET | 0.52 | 0.60 | 0.70 | 0.82 | 1.00 | 0.08 | 0.10 | 0.12 | 0.14 | 0.15 | 0.04 | 0.05 | 0.06 | 0.07 | 0.09 | 0.04 | 0.05 | 0.06 | 0.07 | 0.09 | | | | | |
| WenHai | 0.23 | 0.36 | 0.48 | 0.60 | 0.72 | 0.04 | 0.07 | 0.08 | 0.10 | 0.12 | 0.03 | 0.05 | 0.07 | 0.09 | 0.11 | 0.03 | 0.05 | 0.07 | 0.08 | 0.10 | | | | | |
| XiHe | 0.50 | 0.52 | 0.59 | 0.63 | 0.72 | 0.09 | 0.10 | 0.11 | 0.11 | 0.12 | 0.04 | 0.05 | 0.07 | 0.08 | 0.09 | 0.04 | 0.05 | 0.06 | 0.08 | 0.09 | | | | | |
| **200m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.13 | 0.18 | 0.27 | 0.37 | 0.47 | 0.02 | 0.03 | 0.04 | 0.06 | 0.08 | 0.02 | 0.03 | 0.04 | 0.06 | 0.08 | 0.02 | 0.03 | 0.04 | 0.06 | 0.08 | | | | | |
| GLONET | 0.39 | 0.45 | 0.50 | 0.57 | 0.66 | 0.05 | 0.07 | 0.08 | 0.10 | 0.11 | 0.03 | 0.04 | 0.05 | 0.06 | 0.08 | 0.03 | 0.04 | 0.05 | 0.06 | 0.08 | | | | | |
| WenHai | 0.17 | 0.27 | 0.36 | 0.45 | 0.54 | 0.03 | 0.05 | 0.07 | 0.08 | 0.10 | 0.03 | 0.04 | 0.06 | 0.07 | 0.09 | 0.03 | 0.04 | 0.06 | 0.07 | 0.09 | | | | | |
| XiHe | 0.39 | 0.36 | 0.41 | 0.47 | 0.50 | 0.06 | 0.06 | 0.07 | 0.08 | 0.08 | 0.05 | 0.04 | 0.05 | 0.06 | 0.07 | 0.06 | 0.04 | 0.05 | 0.06 | 0.07 | | | | | |
| **300m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.11 | 0.15 | 0.23 | 0.32 | 0.41 | 0.02 | 0.03 | 0.04 | 0.05 | 0.07 | 0.02 | 0.03 | 0.04 | 0.05 | 0.07 | 0.02 | 0.03 | 0.04 | 0.06 | 0.07 | | | | | |
| GLONET | 0.34 | 0.39 | 0.42 | 0.47 | 0.55 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 | 0.03 | 0.03 | 0.04 | 0.05 | 0.07 | 0.03 | 0.03 | 0.04 | 0.06 | 0.07 | | | | | |
| WenHai | 0.14 | 0.24 | 0.31 | 0.39 | 0.47 | 0.03 | 0.04 | 0.06 | 0.07 | 0.08 | 0.02 | 0.04 | 0.05 | 0.07 | 0.08 | 0.03 | 0.04 | 0.05 | 0.07 | 0.08 | | | | | |
| XiHe | 0.35 | 0.30 | 0.36 | 0.40 | 0.44 | 0.05 | 0.05 | 0.06 | 0.07 | 0.07 | 0.05 | 0.04 | 0.05 | 0.06 | 0.07 | 0.05 | 0.04 | 0.05 | 0.06 | 0.07 | | | | | |
| **500m** | | | | | | | | | | | | | | | | | | | | | | | | | |
| GLO12 | 0.08 | 0.12 | 0.18 | 0.25 | 0.33 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.01 | 0.02 | 0.03 | 0.04 | 0.06 | 0.01 | 0.02 | 0.03 | 0.05 | 0.06 | | | | | |
| GLONET | 0.20 | 0.25 | 0.30 | 0.35 | 0.41 | 0.04 | 0.05 | 0.06 | 0.06 | 0.07 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.03 | 0.03 | 0.04 | 0.05 | 0.06 | | | | | |
| WenHai | 0.11 | 0.19 | 0.26 | 0.31 | 0.38 | 0.02 | 0.04 | 0.05 | 0.06 | 0.07 | 0.02 | 0.04 | 0.05 | 0.06 | 0.07 | 0.02 | 0.04 | 0.05 | 0.06 | 0.07 | | | | | |
| XiHe | 0.27 | 0.24 | 0.28 | 0.31 | 0.33 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.04 | 0.03 | 0.04 | 0.05 | 0.06 | 0.04 | 0.03 | 0.04 | 0.05 | 0.06 | | | | | |

*references*

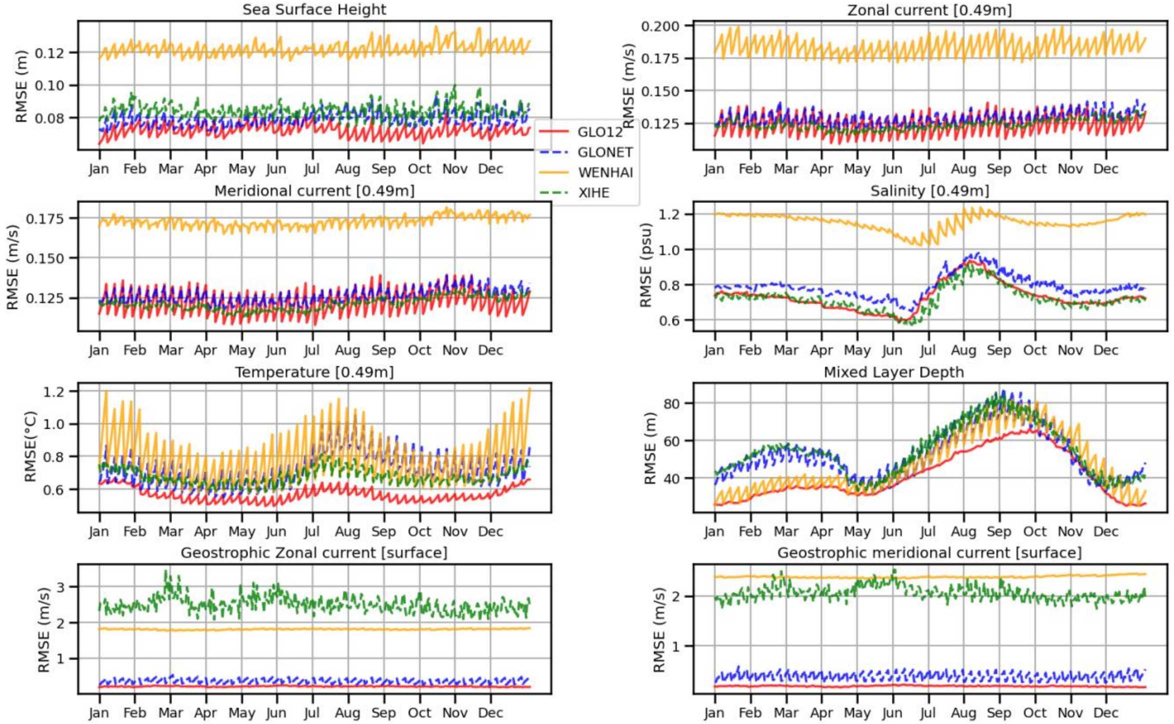


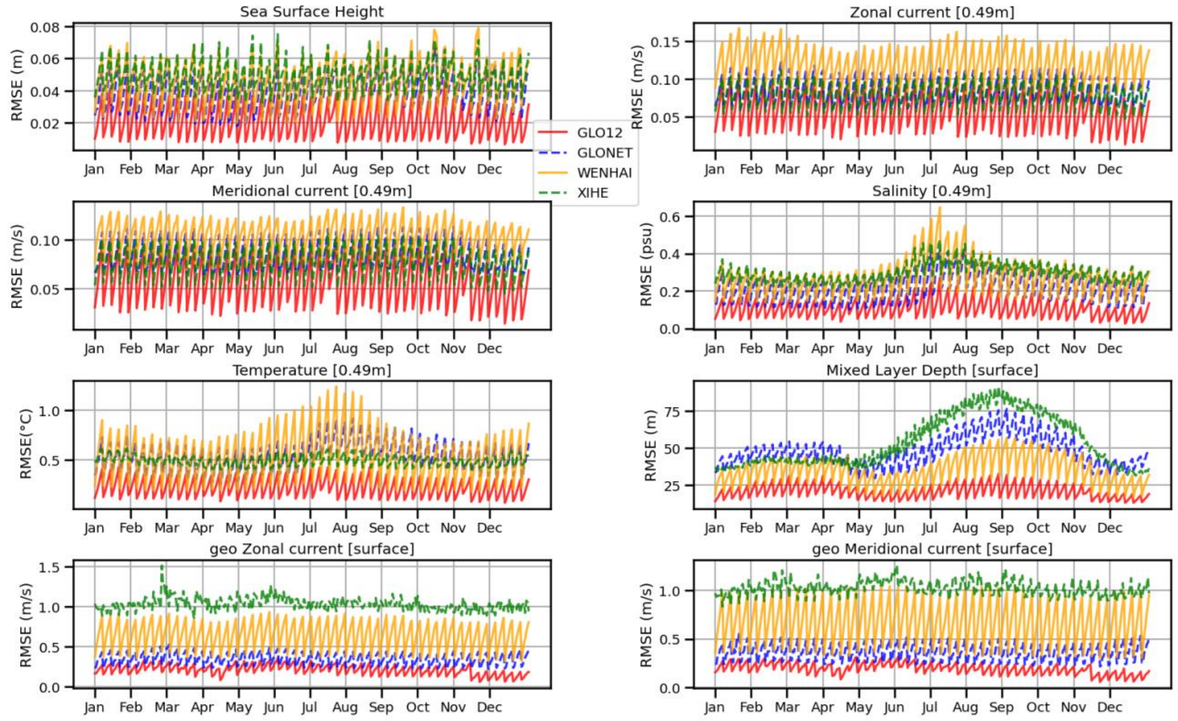



# *References*


GLO12
analysis
λ


GLORYS12


Sea Surface Height
RMSE (m)
Zonal current [0.49m]
RMSE (m/s)
Meridional current [0.49m]
RMSE (m/s)
Salinity [0.49m]
RMSE (psu)
Temperature [0.49m]
RMSE(°C)
Mixed Layer Depth
RMSE (m)
Geostrophic Zonal current [surface]
RMSE (m/s)
Geostrophic meridional current [surface]
RMSE (m/s)
GLO12
GLONET
WENHAI
XIHE
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Sea Surface Height
RMSE (m)
Zonal current [0.49m]
RMSE (m/s)
Meridional current [0.49m]
RMSE (m/s)
Salinity [0.49m]
RMSE (psu)
Temperature [0.49m]
RMSE(°C)
Mixed Layer Depth [surface]
RMSE (m)
geo Zonal current [surface]
RMSE (m/s)
geo Meridional current [surface]
RMSE (m/s)
GLO12
GLONET
WENHAI
XIHE
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

# Future Release

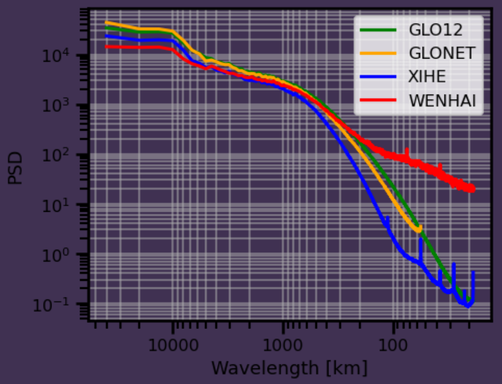
## References

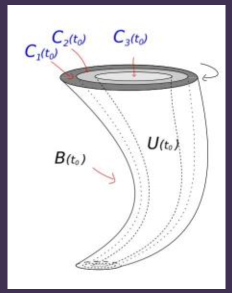
Extend the evaluation period *2025 & 2023*

## Challengers

- *Physics based:* *GLOEns*, *GLO36*
- *ML-based:* Langya, FuXi-Ocean, SeaCast, MedFormer..

## Evaluation metrics




Continuous Ranked Probability Score

## Evaluation Tracks

*Probablistic forecast,* *Seasonal forecast*

*Regional Track,* *ICE*

*1° Track,* *BGC*

# DEMO