SYMPOSIUM OP'24
ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

# Offline Fennel: An Offline Biogeochemical Model within the Regional Ocean Modelling System (ROMS)

**Júlia Crespin**[1], Jordi Solé[2], and Miquel Canals[1]

1. GRC Geociències Marines (GMAR), Departament de Dinàmica de la Terra i de l'Oceà, Universitat de Barcelona; Barcelona, Spain.
2. Institut de Ciències del Mar (CSIC); Barcelona, Spain.

jcrespin@ub.edu

## Introduction

- Ocean biogeochemical models are essential for understanding marine ecosystem dynamics, especially under **climate change**. However, coupled models, which run biogeochemical and physical components simultaneously, require significant computational resources, limiting simulation tests and high-resolution studies.
- The **Offline Fennel model**, implemented within ROMS, addresses this by using hydrodynamic simulations as inputs for separate biogeochemical simulations, improving **computational efficiency**.
- This study evaluates the offline model's performance comparing its accuracy to fully coupled simulations and assessing how mixing schemes and time-steps impact model precision and efficiency.

## Key messages

- ✓ Offline Fennel accurately reproduces nutrient cycling, primary production, and oxygen dynamics in the Gulf of Mexico, with a **mean skill score of 93%** across all key biogeochemical tracers ($NO_3$, $NH_4$, $PO_4$, CHL, and Oxyg).
- ✓ The model **reduced simulation times by up to 87%**, allowing researchers to perform multiple runs efficiently without sacrificing accuracy.
- ✓ Although minor discrepancies were observed, primarily for $NH_4$, results are promising. The differences between tracers are not larger than when choosing different mixing schemes in the same model application.
- ✓ Offline Fennel offers an **efficient** and **accurate tool** for extensive biogeochemical simulations, parameter tuning, and sensitivity testing over large geographic areas or extended periods, making it an ideal solution for future climate prediction efforts and environmental assessments.

## Results

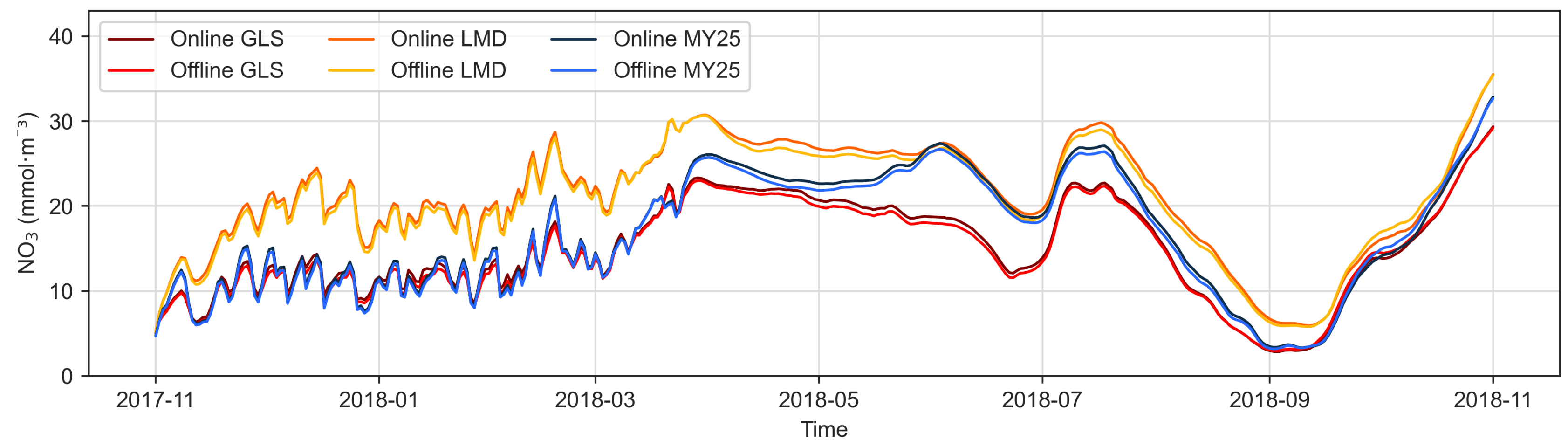


*Figure 1.* ***$NO_3$ time-series for on- and offline (x5) simulations across mixing schemes at the surface layer.***

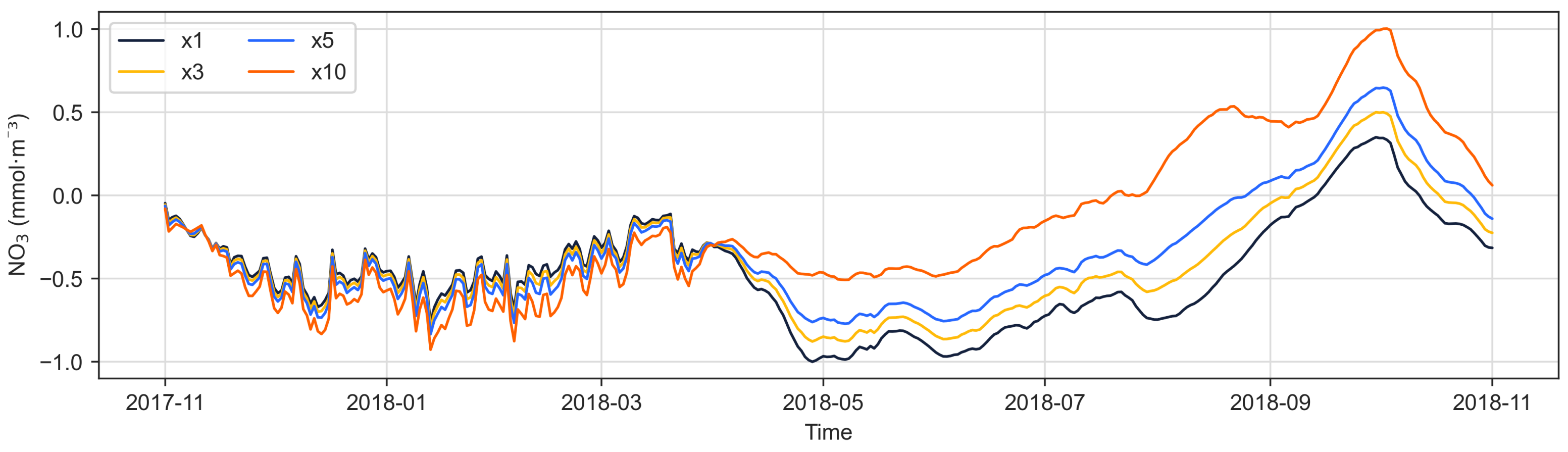


*Figure 2.* ***$NO_3$ differences across time-steps in GLS configuration at the surface layer.***

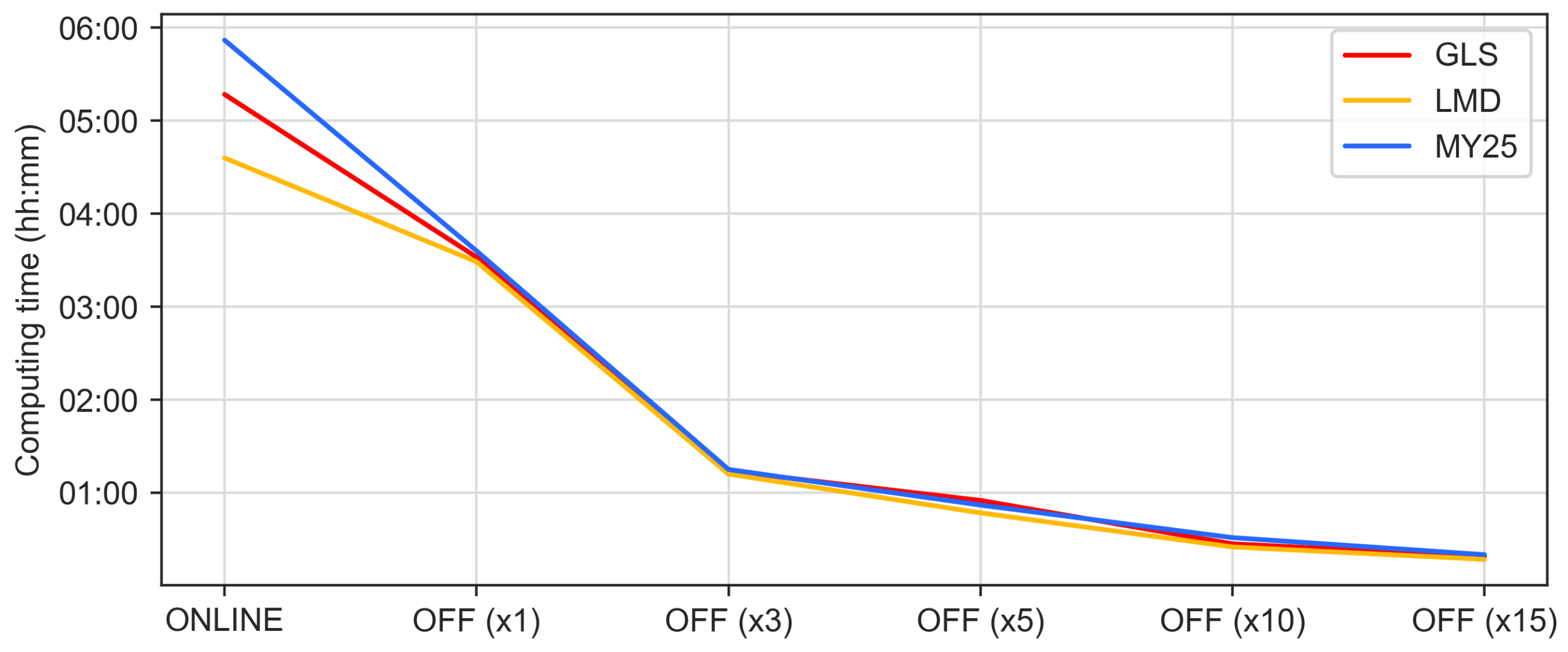


*Figure 3.* ***Computation time (hh:mm) of online and offline simulations across all mixing schemes.***

| Tracer | Mixing Scheme | x1 | x3 | x5 | x10 |
|---|---|---|---|---|---|
| $NO_3$ | *GLS* | 95 | 95 | 95 | 95 |
| | *LMD* | 95 | 95 | 95 | 94 |
| | *MY25* | 96 | 96 | 96 | 95 |
| $NH_4$ | *GLS* | 84 | 85 | 85 | 86 |
| | *LMD* | 81 | 82 | 82 | 83 |
| | *MY25* | 82 | 83 | 83 | 84 |
| $PO_4$ | *GLS* | 96 | 96 | 96 | 95 |
| | *LMD* | 96 | 97 | 96 | 96 |
| | *MY25* | 97 | 97 | 97 | 96 |
| CHL | *GLS* | 92 | 92 | 92 | 92 |
| | *LMD* | 93 | 93 | 93 | 92 |
| | *MY25* | 93 | 93 | 93 | 92 |
| Oxyg | *GLS* | 98 | 98 | 98 | 98 |
| | *LMD* | 98 | 98 | 98 | 97 |
| | *MY25* | 98 | 98 | 98 | 98 |

*Table 1.* ***Skill Scores [%] of key biogeochemical tracers comparing offline and online simulations across all time-steps and mixing schemes.***

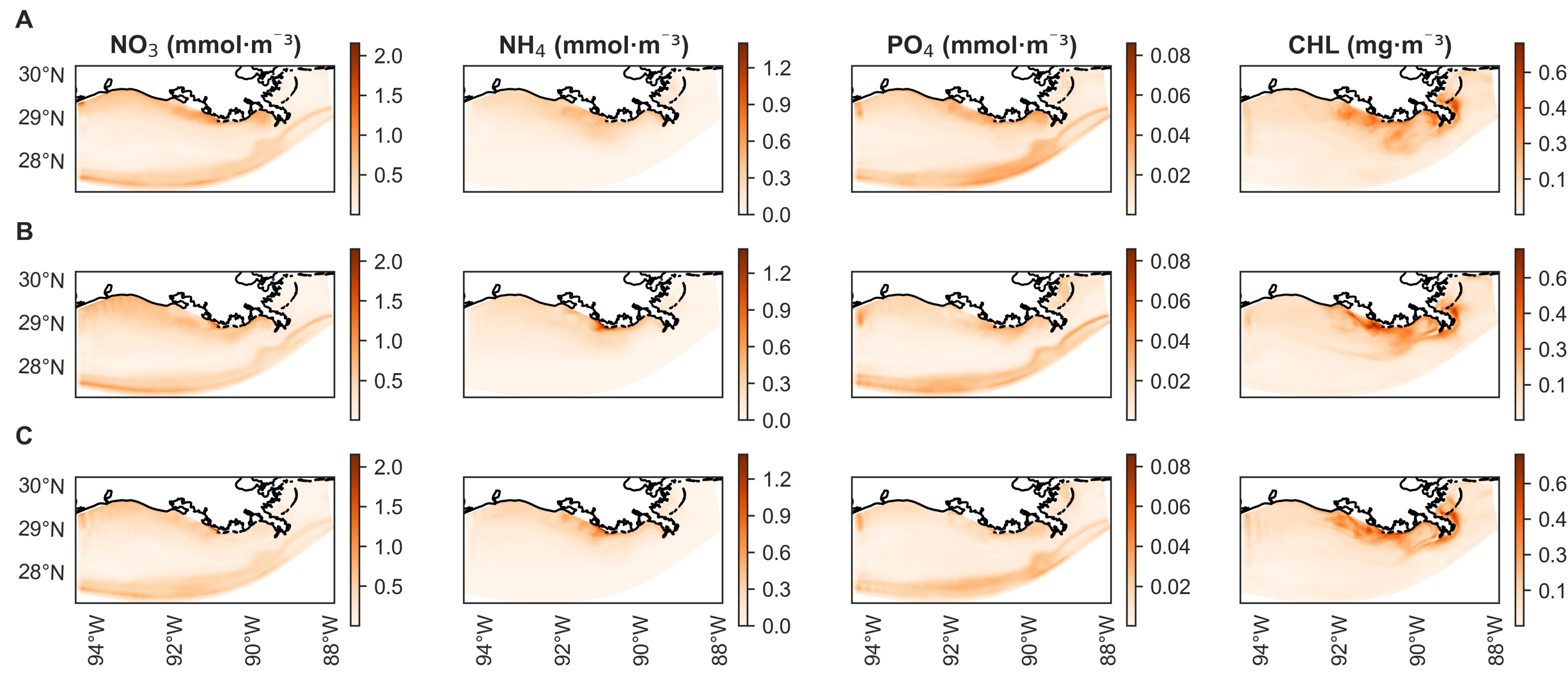
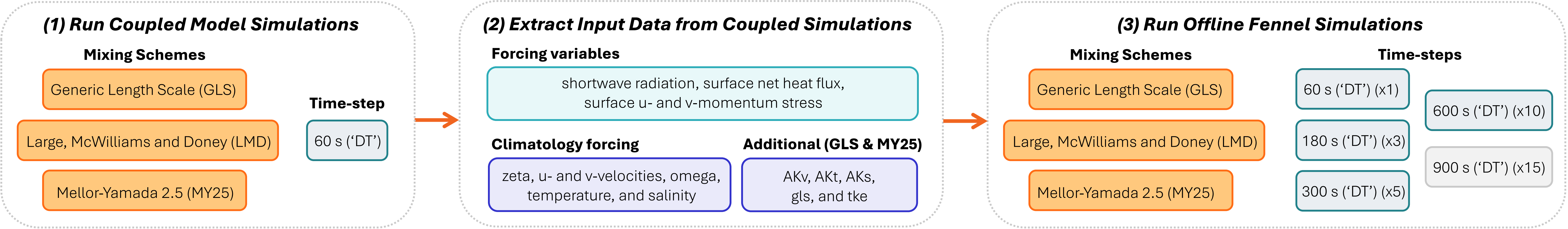


*Figure 4.* ***Mean RMSE across depth of key biogeochemical tracers, between offline (x5 time-step) and online simulations using (A) GLS, (B) LMD, and (C) MY25 mixing schemes.***

## Offline Methodology



***(1) Run Coupled Model Simulations***

**Mixing Schemes**
- Generic Length Scale (GLS)
- Large, McWilliams and Doney (LMD)
- Mellor-Yamada 2.5 (MY25)

**Time-step**
- 60 s ('DT')

***(2) Extract Input Data from Coupled Simulations***

**Forcing variables**
- shortwave radiation, surface net heat flux, surface u- and v-momentum stress

**Climatology forcing**
- zeta, u- and v-velocities, omega, temperature, and salinity

**Additional (GLS & MY25)**
- AKv, AKt, AKs, gls, and tke

***(3) Run Offline Fennel Simulations***

**Mixing Schemes**
- Generic Length Scale (GLS)
- Large, McWilliams and Doney (LMD)
- Mellor-Yamada 2.5 (MY25)

**Time-steps**
- 60 s ('DT') (x1)
- 180 s ('DT') (x3)
- 300 s ('DT') (x5)
- 600 s ('DT') (x10)
- 900 s ('DT') (x15)

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