Remote Sensing-derived Zooplankton Biomass and Grazing: Analyzing Errors Associated with Models

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Objectives and Methods

Objectives

- Evaluate the performance of a food-web model (Siegel et al., 2014) for estimating zooplankton grazing rates in the Gulf of Mexico (GoM)
- Evaluate the performance of an inverted NEMURO model (Kishi et al., 2007) for estimating zooplankton grazing rate and zooplankton biomass in the GoM
- Analyze the sensitivity of the model to the method of calculation of small and large phytoplankton growth rate ($\frac{dP}{dt}$)
- Analyze errors associated with changes in mixed layer depth (MLD) and in/exclusion of the entrainment term in the Food-web model
- Estimate zooplankton grazing rates on small phytoplankton (SP), large phytoplankton (LP) and biomass using remotely sensed data (MODIS-Aqua) in the GoM

Methods

- These two methods are evaluated by comparing them with simulated grazing rates estimated by coupled NEMURO-HYCOM which serve as "truth or reference data."
- To estimate grazing rates using satellite data, size-specific net primary production (NPP), phytoplankton carbon biomass, and growth rate data are retrieved using the carbon, absorption, and fluorescence euphotic-resolving (CAFE) model (Silsbe et al., 2016) from MODIS-Aqua. Then, the food-web model (eq.1) and the inverted-NEMURO (Figure 1 & Eq.2) are applied to satellite data to retrieve grazing rates and zooplankton biomass. Ultimately, results will be compared with *in situ* data (not shown here but used for the model validation).

$$G_i = \frac{NPP_i}{Zeu} - \frac{dp_i}{dt} - 0.1p_i - \delta_{i,M}\frac{AlgEZ}{Zeu} \quad , AlgEZ = 0.1 \times NPP_m \qquad \text{eq.1}$$

(Siegel et al., 2014& Stukel et al., 2015)

$$G_i = NPP_i - \frac{dp_i}{dt} - ResP_i - MorP_i - ExcP_i \qquad \text{eq.2}$$

(Kishi et al., 2007)

- The sensitivity of the methods to $\frac{dP}{dt}$ calculation methods was tested by examining:
  - Biological Disequilibrium ($\frac{dP}{dt}$=0)
  - Time dependence ($\frac{dP}{dt} = \frac{(P_2-P_1)}{\Delta t}$)
  - $\frac{dP}{dt}$ = empirical function of NPP
- The sensitivity of the Food-web model to in/exclusion of entrainment was tested
- The sensitivity of the inverted model to MLD errors was evaluated : MLD ±20

Data

The input data for the food-web model (Siegel et al., 2014) and the inverted-NEMURO model were obtained from a coupled and validated NEMURO-HYCOM model. The input data (e.g. Figure 2) are:

- Size-specific phytoplankton biomass (P) Size-specific net primary production (NPP)
- Temperature
- Photosynthetically active radiation (PAR)
- MLD and euphotic zone (Zeu)

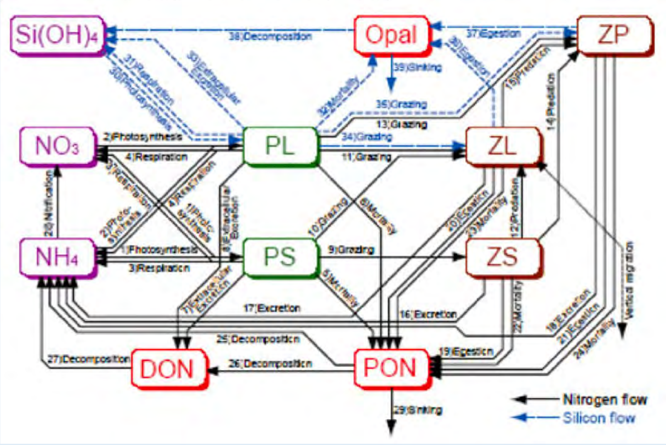

Figure 1. Schematic view of the NEMURO lower trophic level ecosystem model

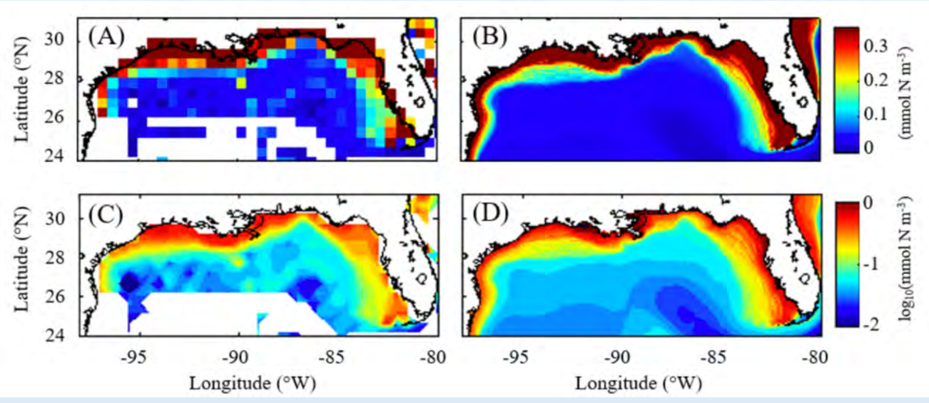

Figure.2 . Comparison of climatological depth averaged mesozooplankton biomass (mmol N m-3) between SEAMAP observations (left) and model output (right) (Shropshire, 2019)

To estimate zooplankton grazing rates and biomass from MODIS- Aqua, the L3 8-day products L3 products (http://oceancolor.gsfc.nasa.gov/) were processed. the CAFE model uses five GIOP-DC IOPs (aϕ(443 nm), adg(443 nm), bbp(443 nm), Sdg, and η), Chl a, PAR, and SST.
The input data for the food-web model and the inverted-NEMURO obtained from CAFE model are:

- Size-specific MLD integrated NPP and phytoplankton biomass (Mouw and Yoder, 2010)
- Figure 3 A-D
- MLD and Zeu

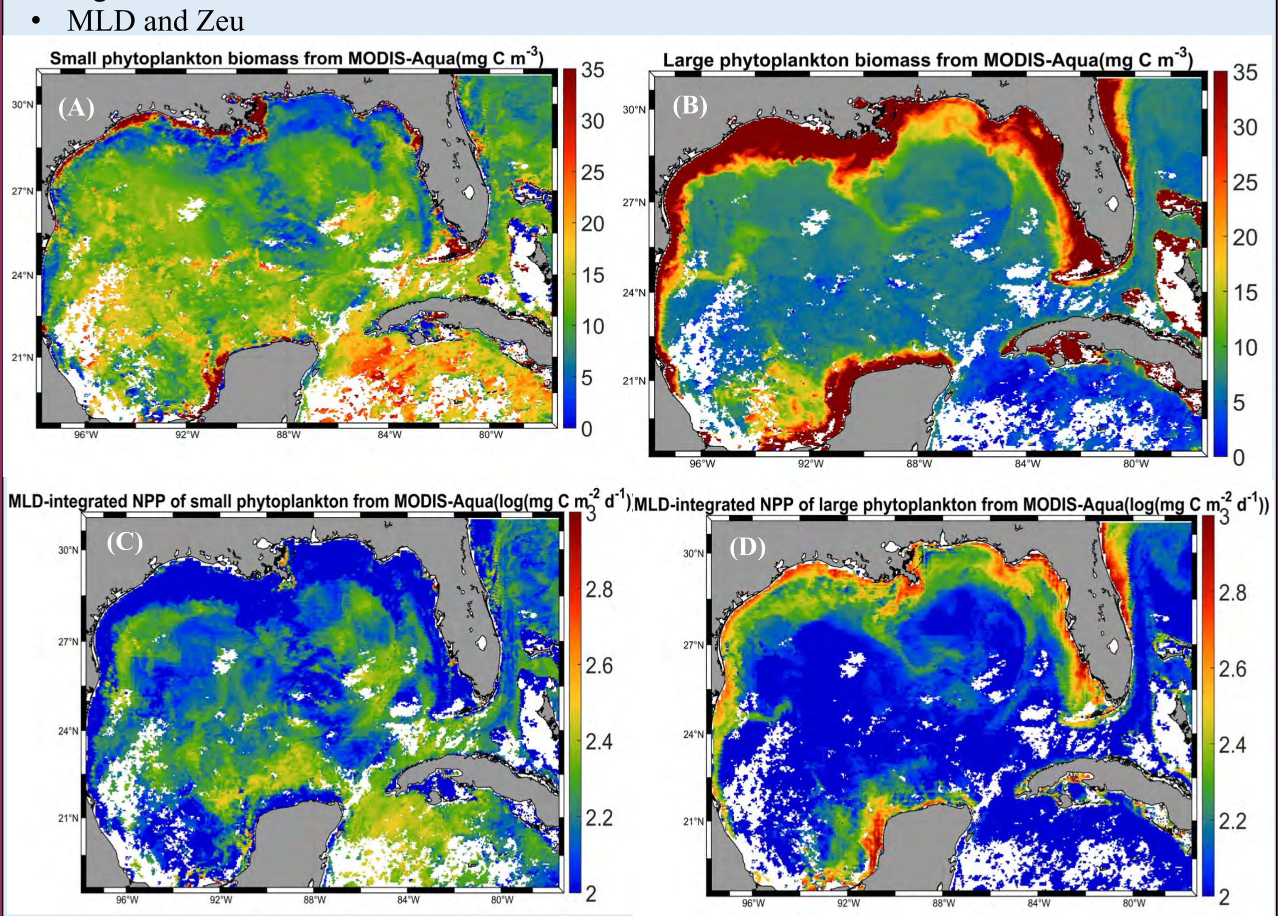

Figure 3. (A) Biomass of SP, (B) LP , (C) MLD-integrated NPPS and (D) NPPL from MODIS-Aqua for October 16, 2003.

Results

Both models perform well, but we can get size-specific biomass, grazing rate and potentially other parameters from the inverted model

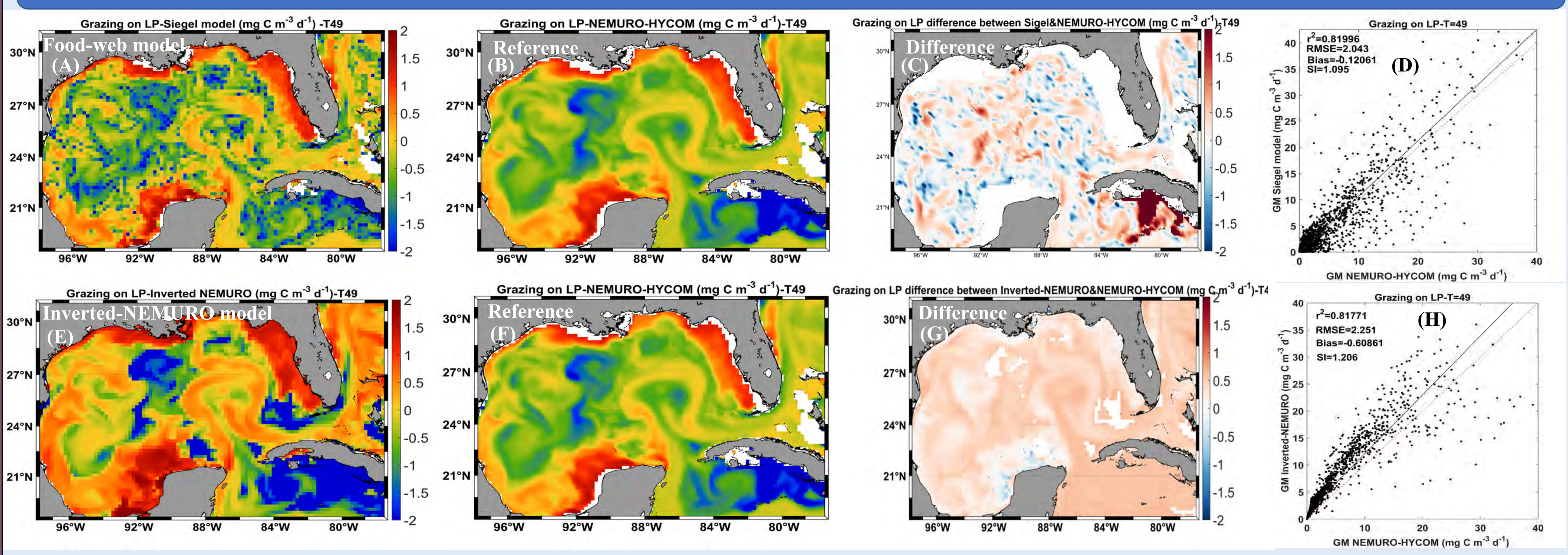

Figure 3. Top panel: grazing rates on LP estimated by (A) Food-web model, (B) reference, (C) the difference, and (D) match-up comparison between the estimated grazing rates, and lower panel: grazing rates on LP estimated by (E) the inverted-NEMURO, (F) reference, (G) the difference, and (H) match-up comparison between the estimated grazing rates. Color bars show log10.

Grazing rate on large phytoplankton is best estimated, when $\frac{dPL}{dt}$ is calculated using $\frac{\Delta p}{\Delta t}$ method
Grazing rate on small phytoplankton is best estimated, when $\frac{dPS}{dt}$=0

Inverted Model | **Food-Web Model-Entrainment Included** | **Food Web Model-Entrainment Excluded**

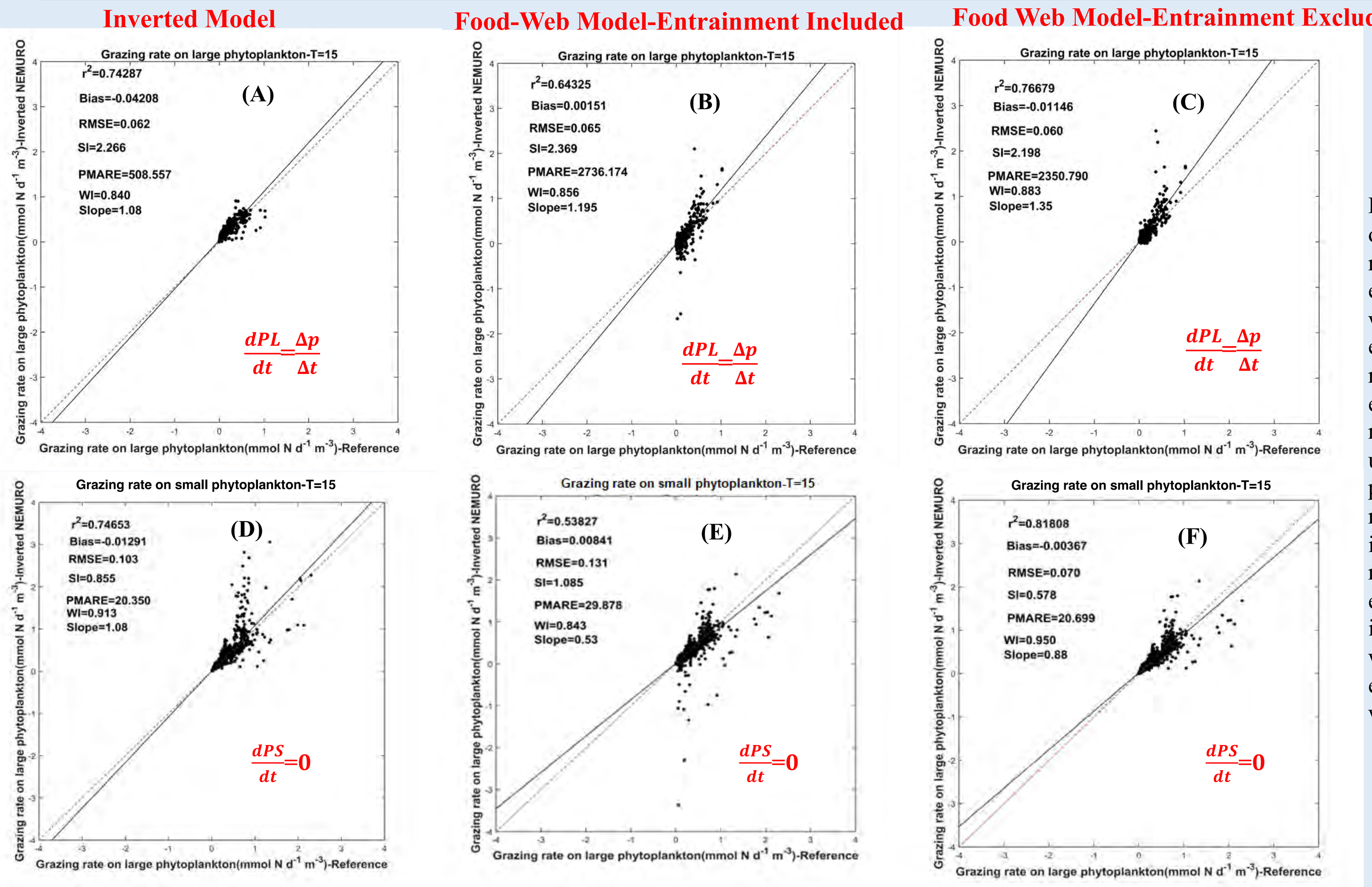

Figure 4. Top panel: Match-up comparison of grazing rates on LP between (A) reference and the inverted –NEMURO estimations, (B) reference and the Food-web model estimations when the entrainment term was included, and (C) reference and the Food-web model estimations when the entrainment term was not included. Here, dp/dt was calculated using the forward method, and lower panel: Match-up comparison of grazing rates on SP between (A) reference and the inverted –NEMURO estimations, (B) reference and the Food-web model estimation when the entrainment term included, and (C) reference and the Food-web model estimation when the entrainment term not included,. Here, dp/dt was assumed zero.

The inverted-model is sensitive to how we calculate $\frac{dP}{dt}$: better estimations of LZ when $\frac{dPL}{dt}\frac{\Delta p}{\Delta t}$

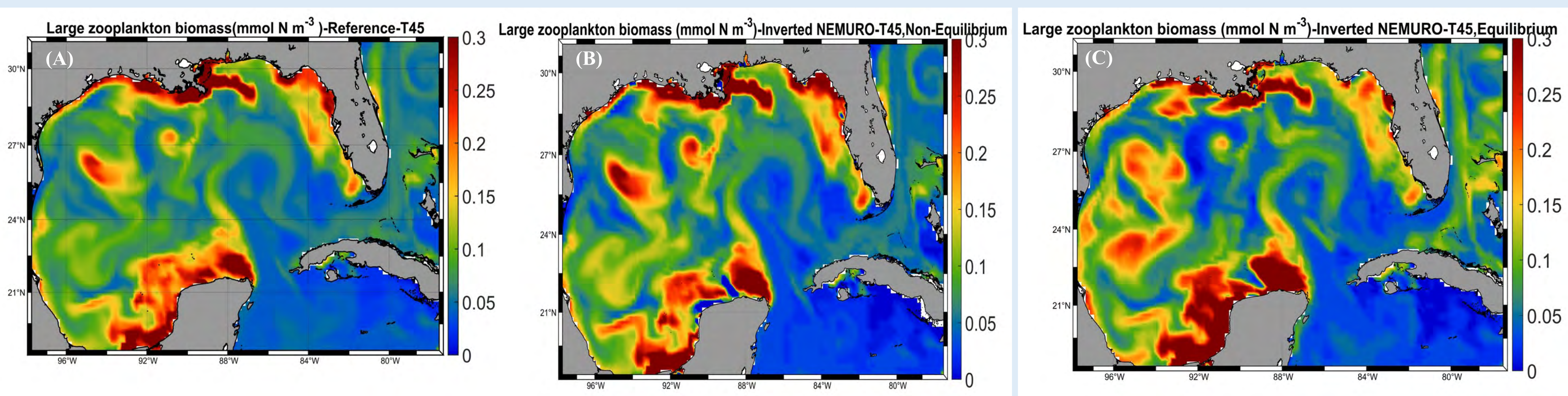

Figure 5. Large zooplankton biomass estimations from (A) reference, (B) Inverted model (non-equilibrium) , and (C) Inverted model (equilibrium)

No clear looser!

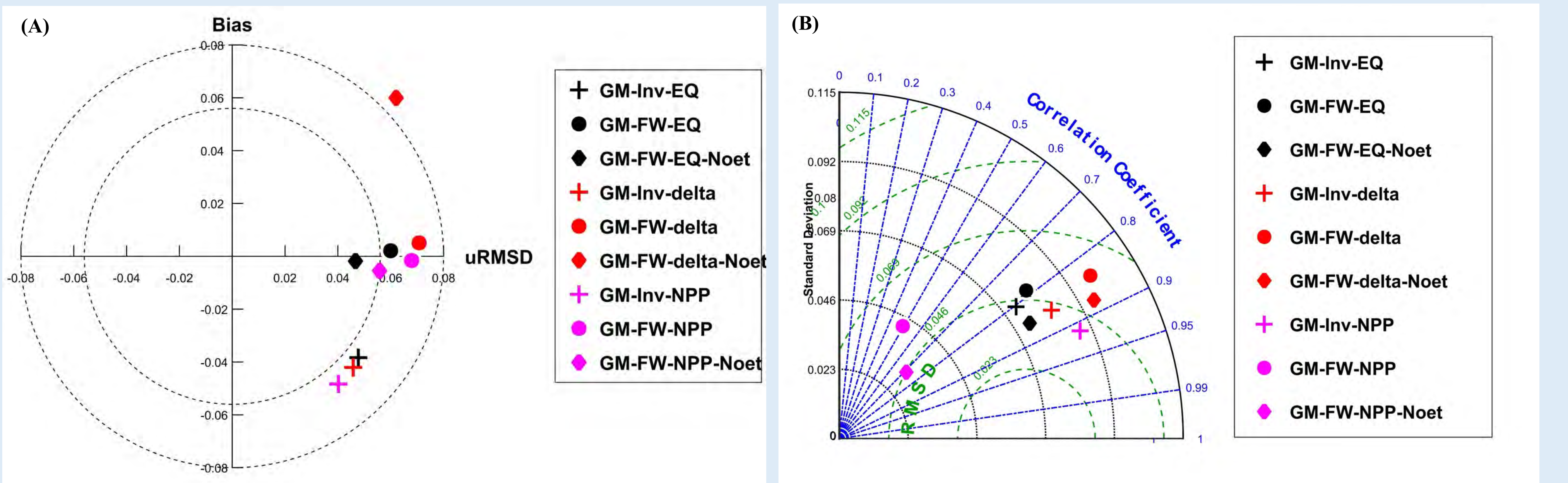

Figure 6. Visualization of the error in grazing on LP the form of Target (A) and Taylor diagrams of the statistical validation between the reference, the Food-web model and the inverted model.

Results (Cont.)

For positive MLD error: Grazing on large/small phytoplankton ↑ (29%, 21%)
& NPPL/S ↑ (28%, 34%)

For negative MLD error : Grazing on large/small phytoplankton ↓ (11%, 10%) & NPPL/S ↓ (13%, 14%)

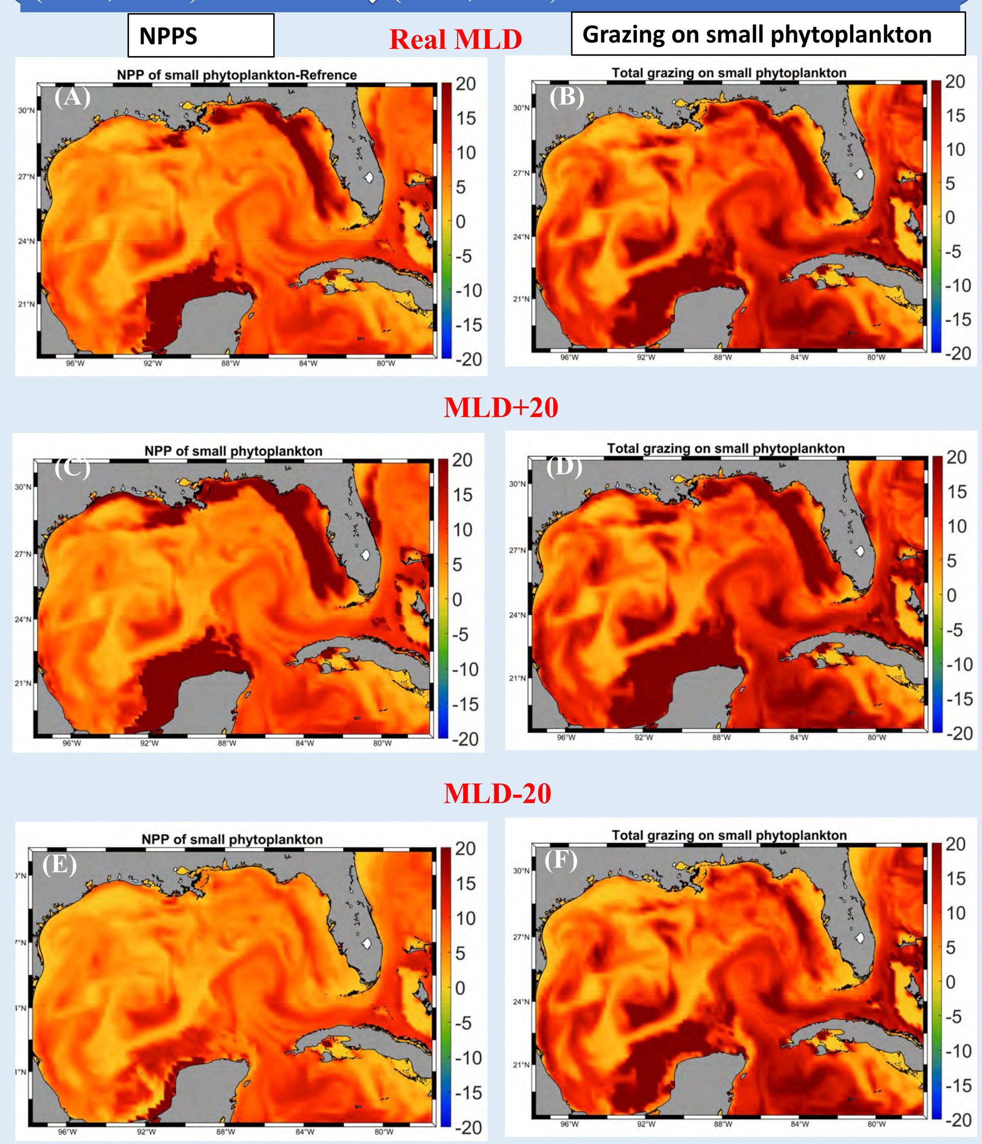

Figure 7. Left panel: NPP of small phytoplankton (A) real MLD, (C) MLD+20, and (E) MLD-20 were used. Right panel: grazing rate on small phytoplankton (B) real MLD, (D) MLD+20, and (F) MLD-20 were used

Sensitivity of solutions to the fraction of large and small phytoplankton

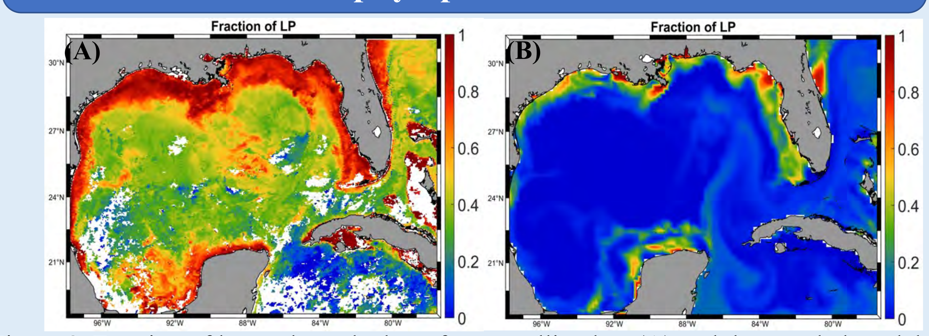

Figure 8. Fraction of large phytoplankton from satellite data (A) and the coupled model

Size-specific zooplankton biomass & grazing rate from MODIS

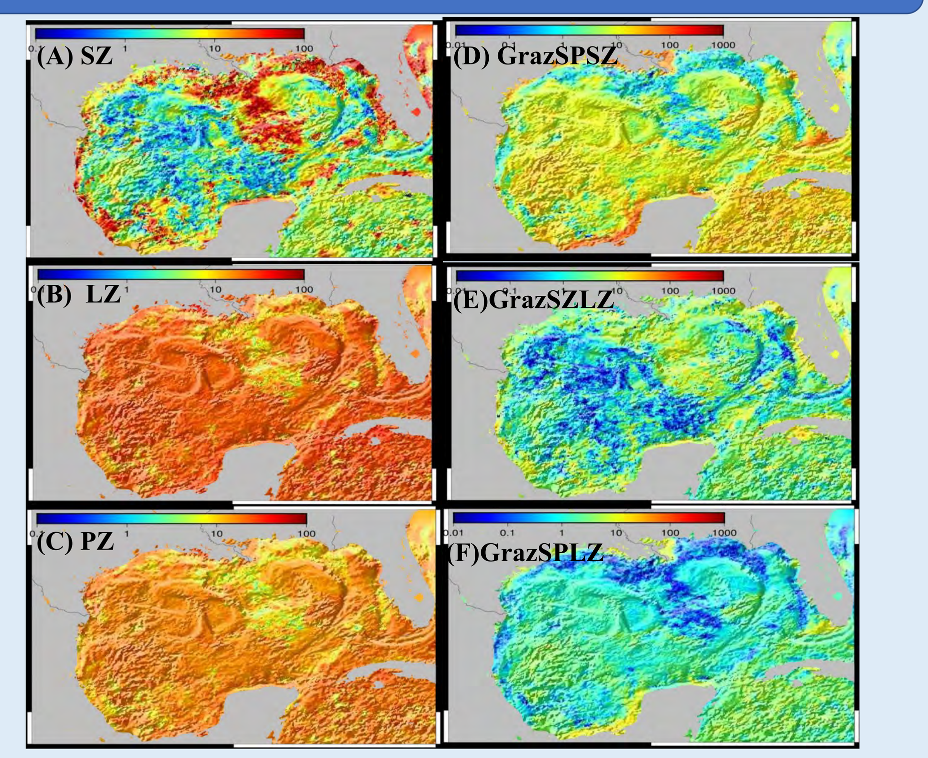

Figure 9. Left panel: Zooplankton biomass (A-C), right panel: grazing rate (D-F)

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