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Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

# Bridging Scales in Mediterranean Biogeochemical Prediction

## A High-Order Ensemble Assimilation Coupled with AI-Driven Downscaling

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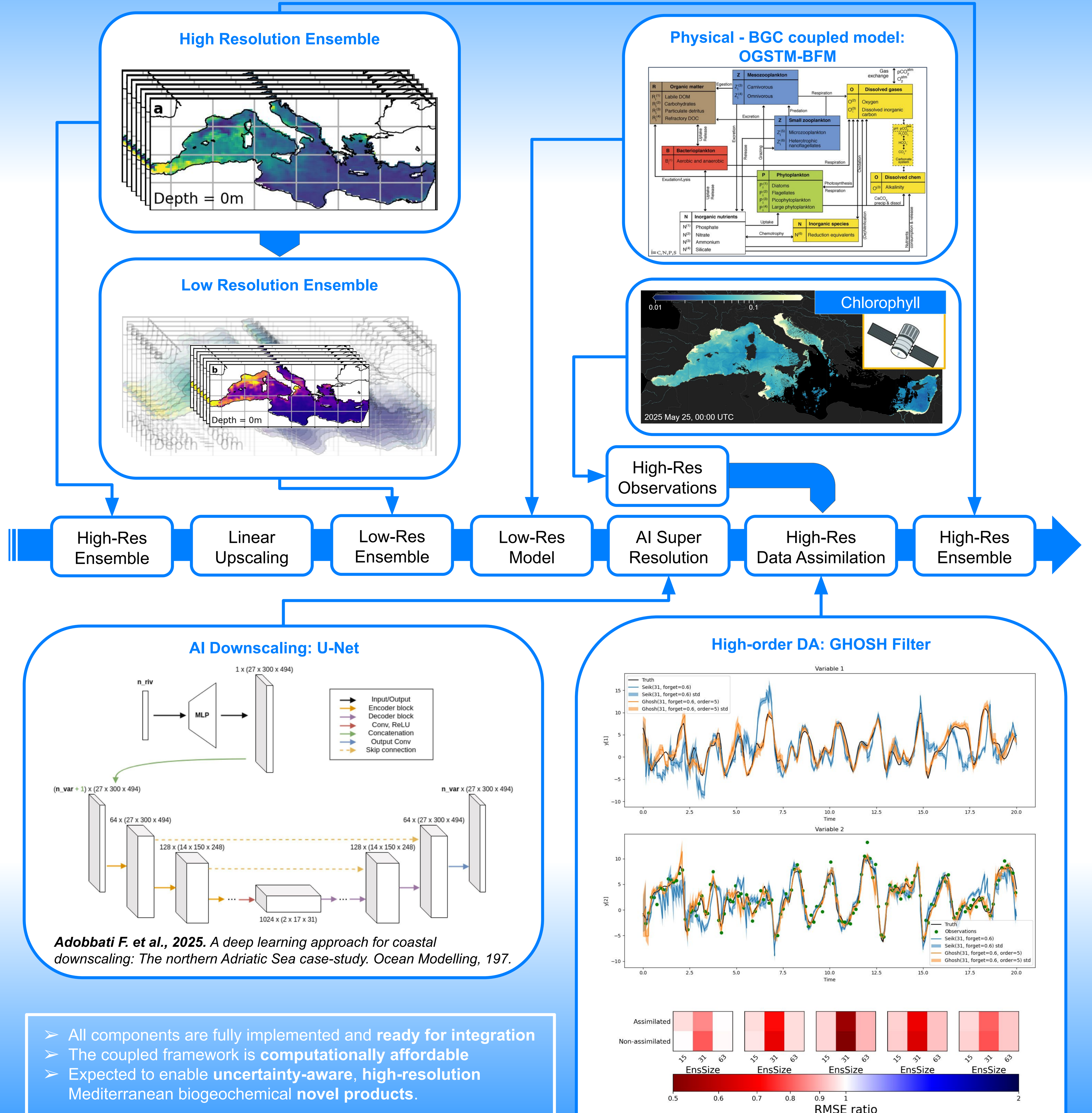
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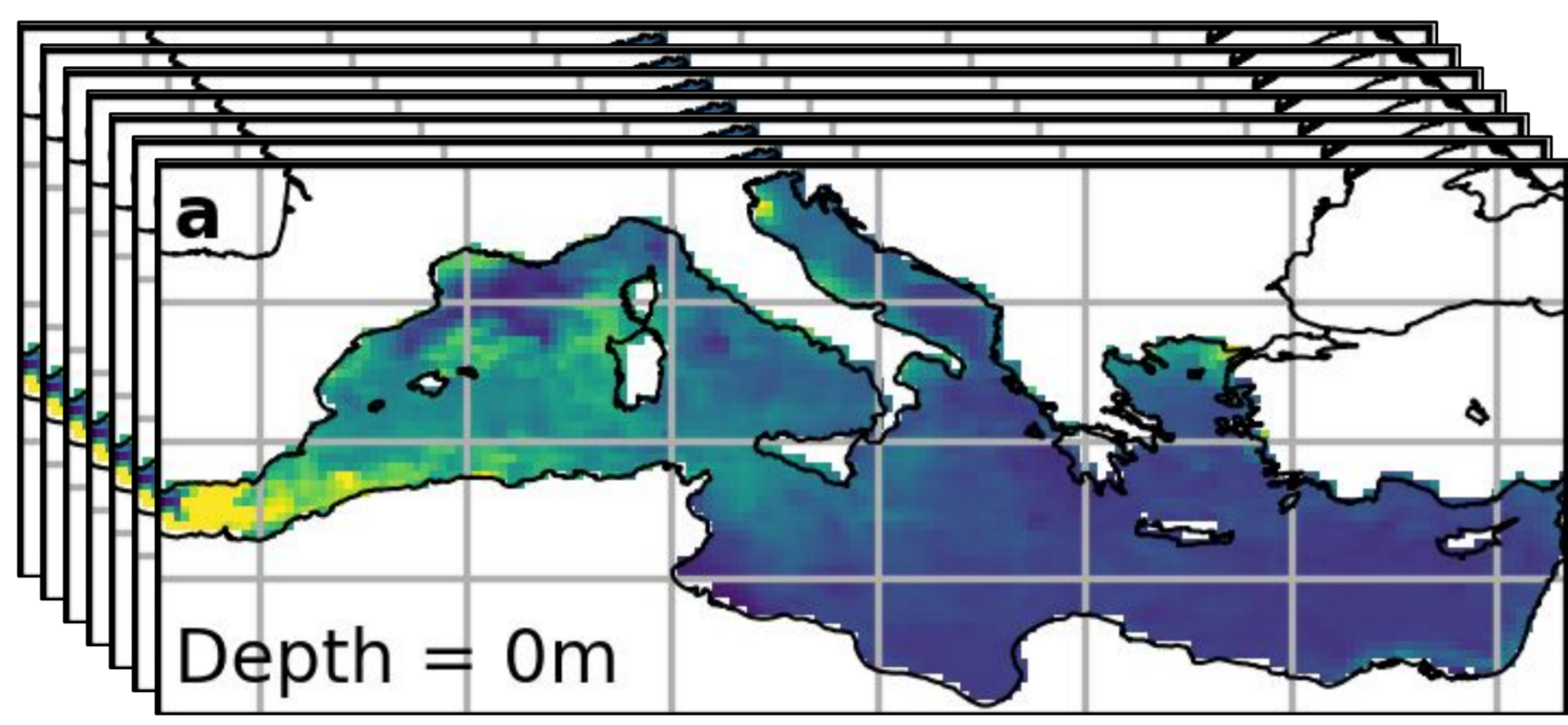
Operational coastal applications require **fine-scale** biogeochemical information, while ensemble data assimilation at operational resolution remains **computationally demanding**.

We address this scale–cost gap in the **Mediterranean forecasting system** by combining a high-order Ensemble Kalman Filter (**GHOSH**) with an **AI-based downscaling** model built on a 3D UNet-like architecture.

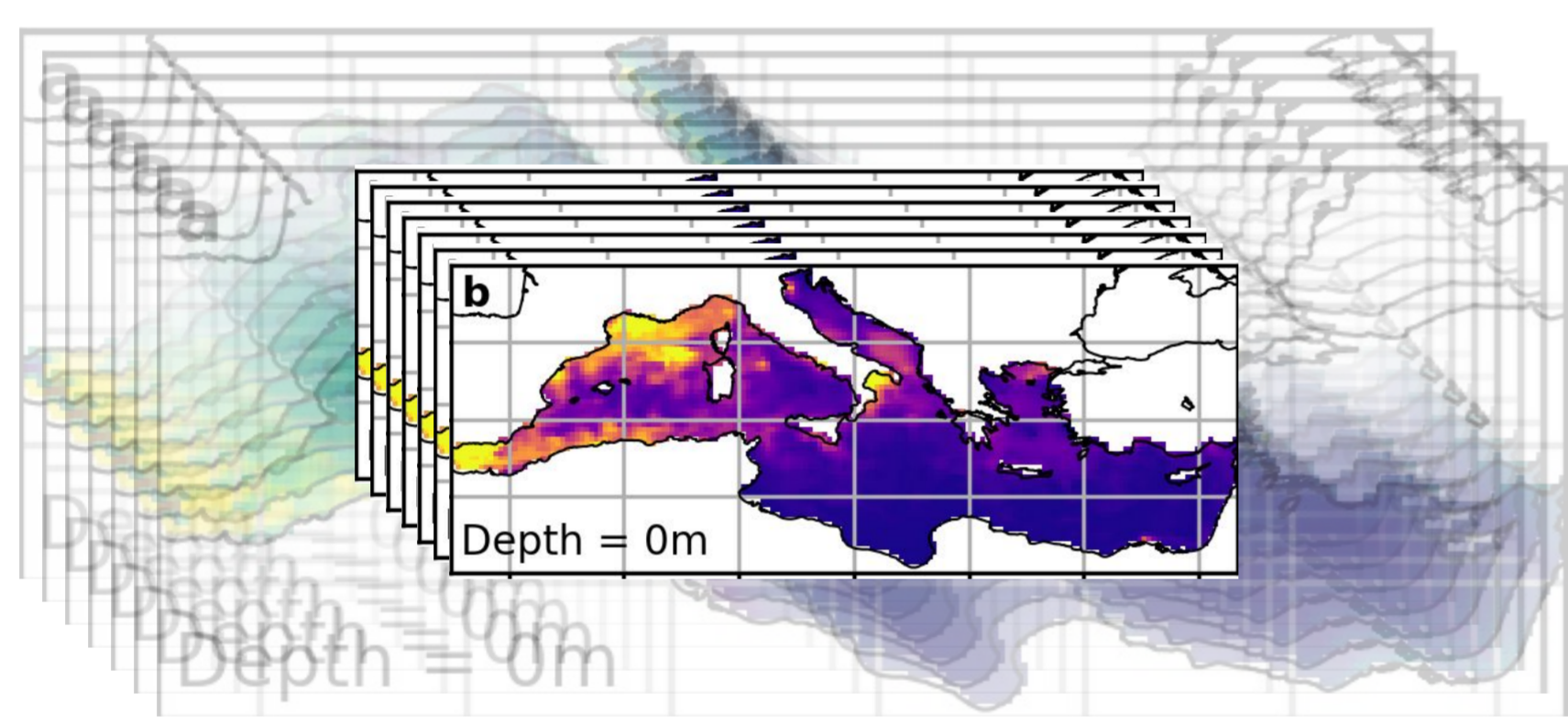
- Ensemble members evolve at low resolution to reduce cost
- AI reconstructs fine-scale physical and biogeochemical structures
- Data assimilation produces high-resolution state estimation
- High-resolution uncertainty quantification



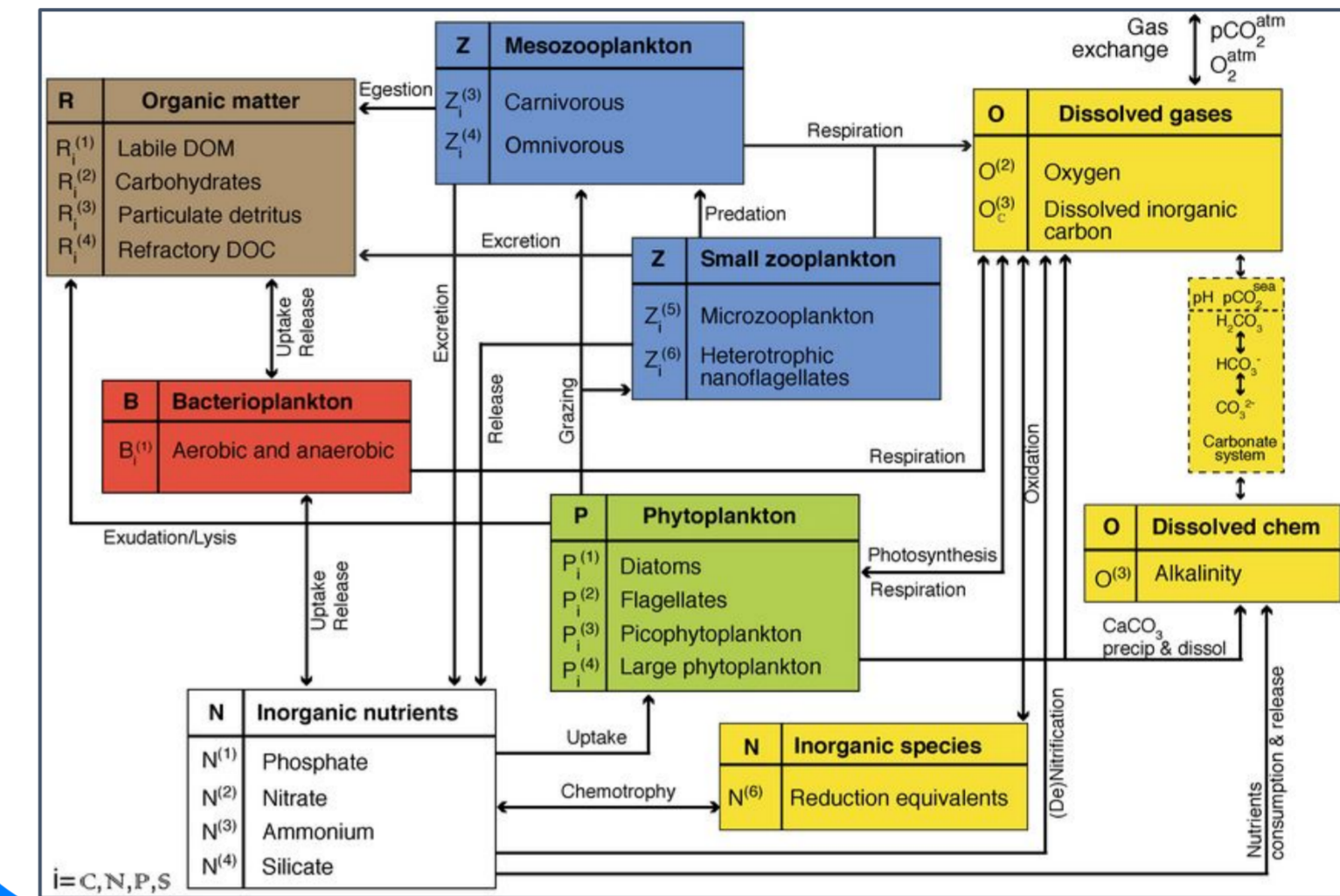
High Resolution Ensemble



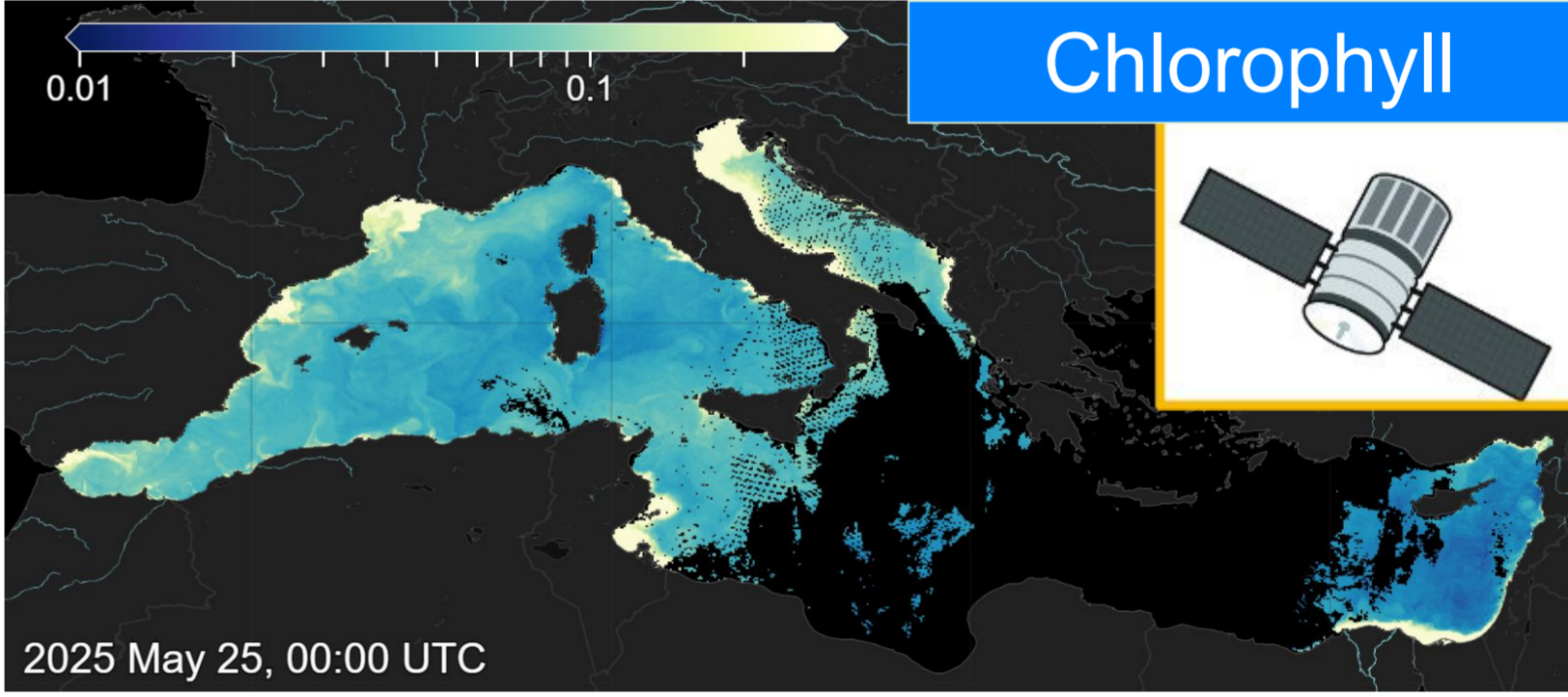
Low Resolution Ensemble



Physical - BGC coupled model: OGSTM-BFM



Chlorophyll



High-Res Ensemble

Linear Upscaling

Low-Res Ensemble

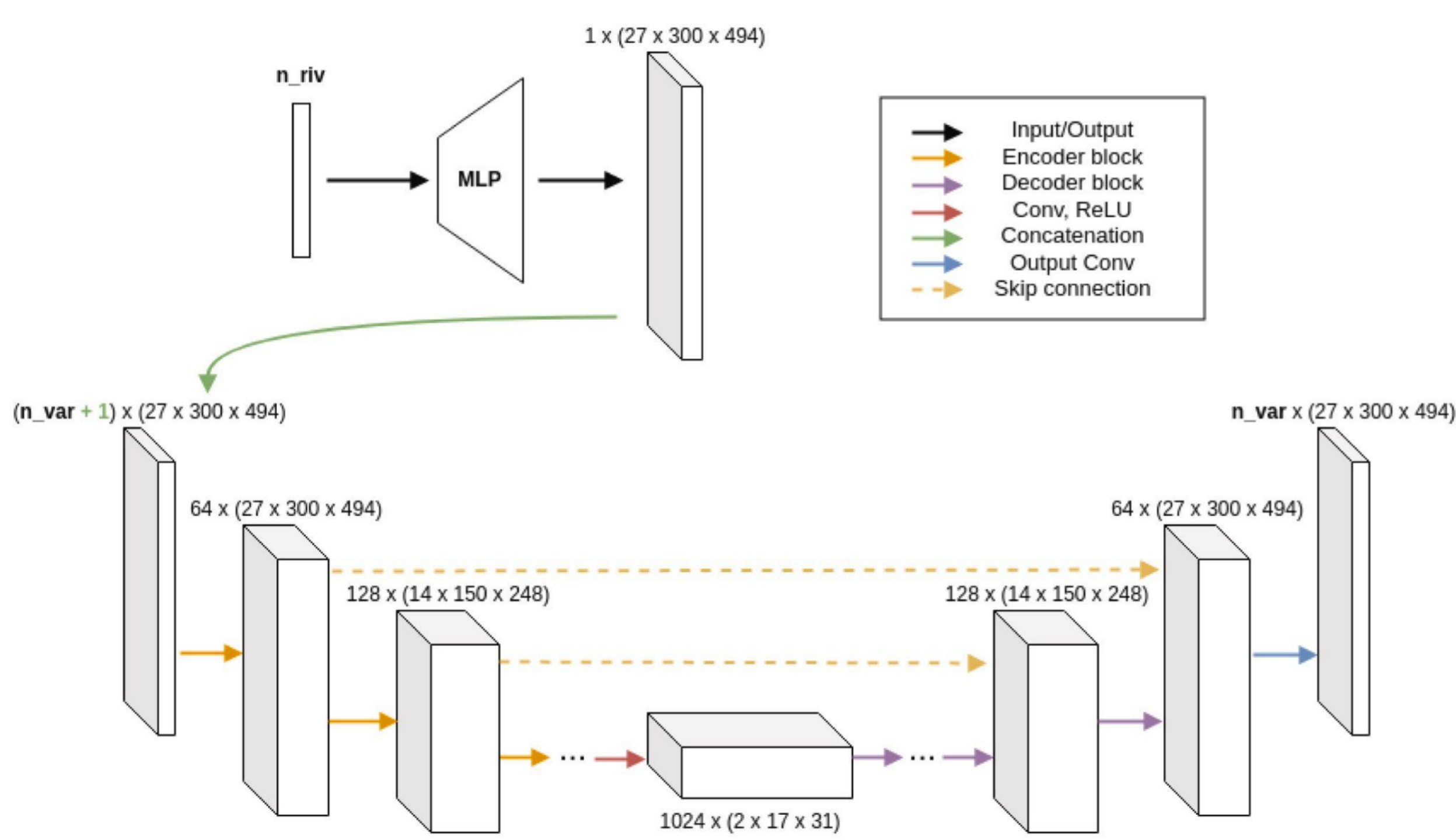
Low-Res Model

AI Super Resolution

High-Res Data Assimilation

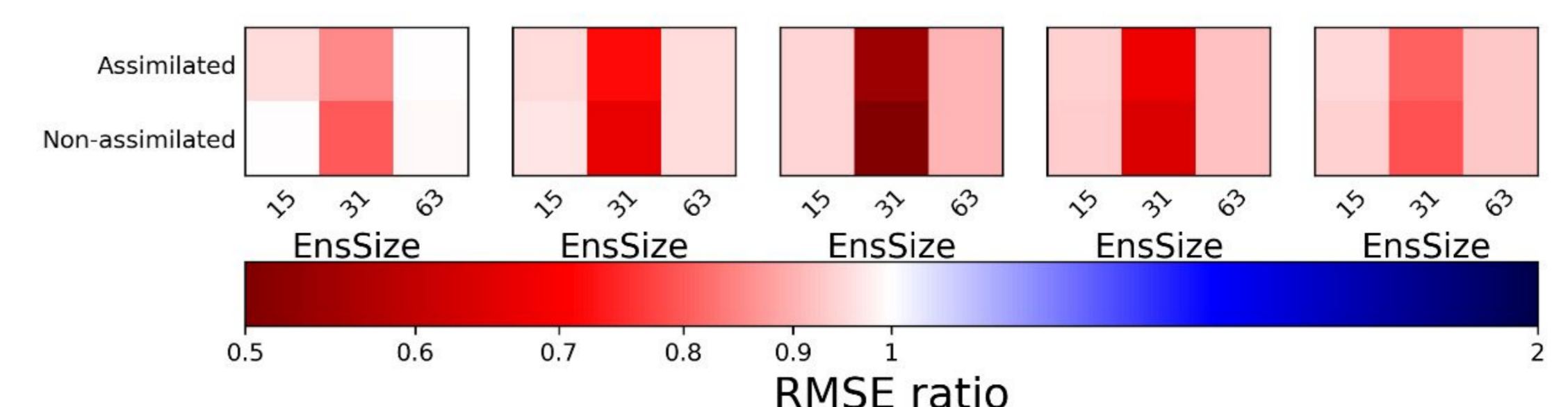
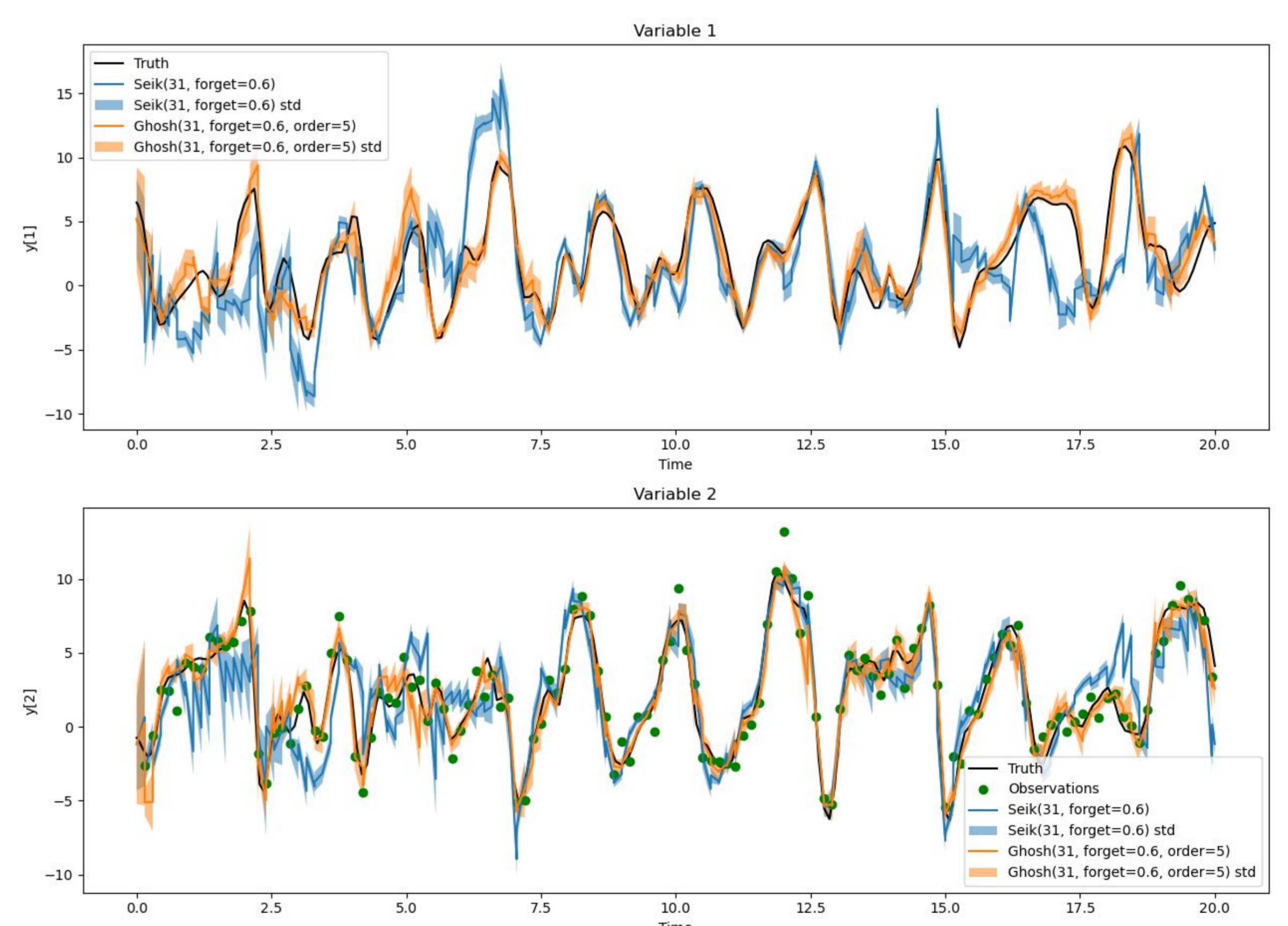
High-Res Ensemble

AI Downscaling: U-Net



Adobati F. et al., 2025. A deep learning approach for coastal downscaling: The northern Adriatic Sea case-study. Ocean Modelling, 197.

High-order DA: GHOSH Filter



- All components are fully implemented and ready for integration
- The coupled framework is **computationally affordable**
- Expected to enable **uncertainty-aware, high-resolution** Mediterranean biogeochemical **novel products**.

Spada S. et al. 2023. GHOSH v1.0.0: a novel Gauss-Hermite High-Order Sampling Hybrid filter for computationally efficient data assimilation in geosciences. Geoscientific Model Development Discussions 1–43.