Links between coastal upwelling and deep-sea ecosystems in the California Current System

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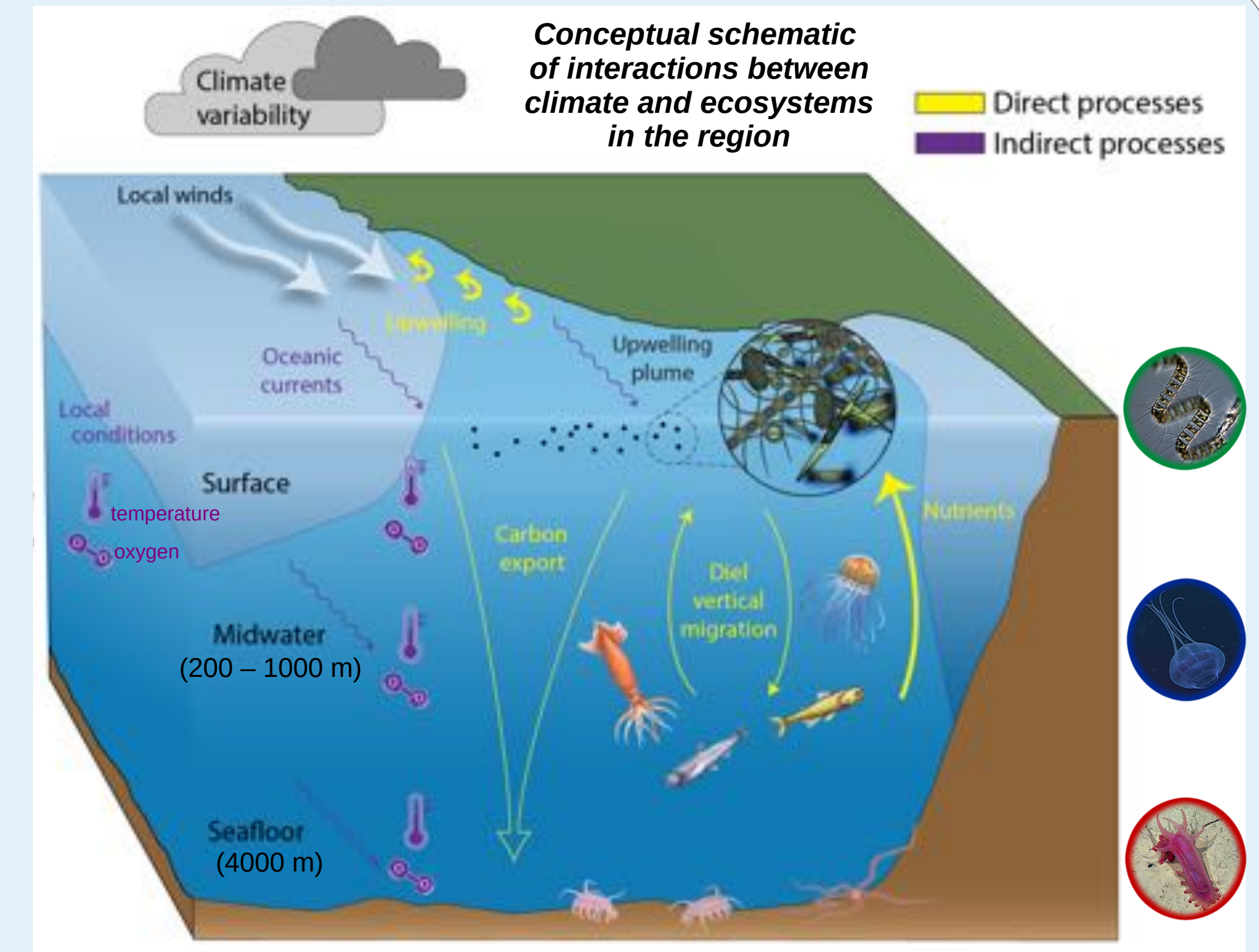[1]Monterey Bay Aquarium Research Institute (MBARI), [2]CenCOOS, [3]retired

Introduction

➢ California Current Upwelling System: surface productivity is primarily supported by wind-driven coastal upwelling.

➢ Connections between upwelling and surface processes are well understood, less so for the deep sea (although there are correlations).

➢ We look at **processes** by which coastal upwelling is linked to deep-sea particulate organic carbon (POC) flux (**left**) and ecological variability (**right**) using long-term time series.

➢ Upwelling is linked to climatic modes (eg NPGO) and expected to be impacted by climate change.
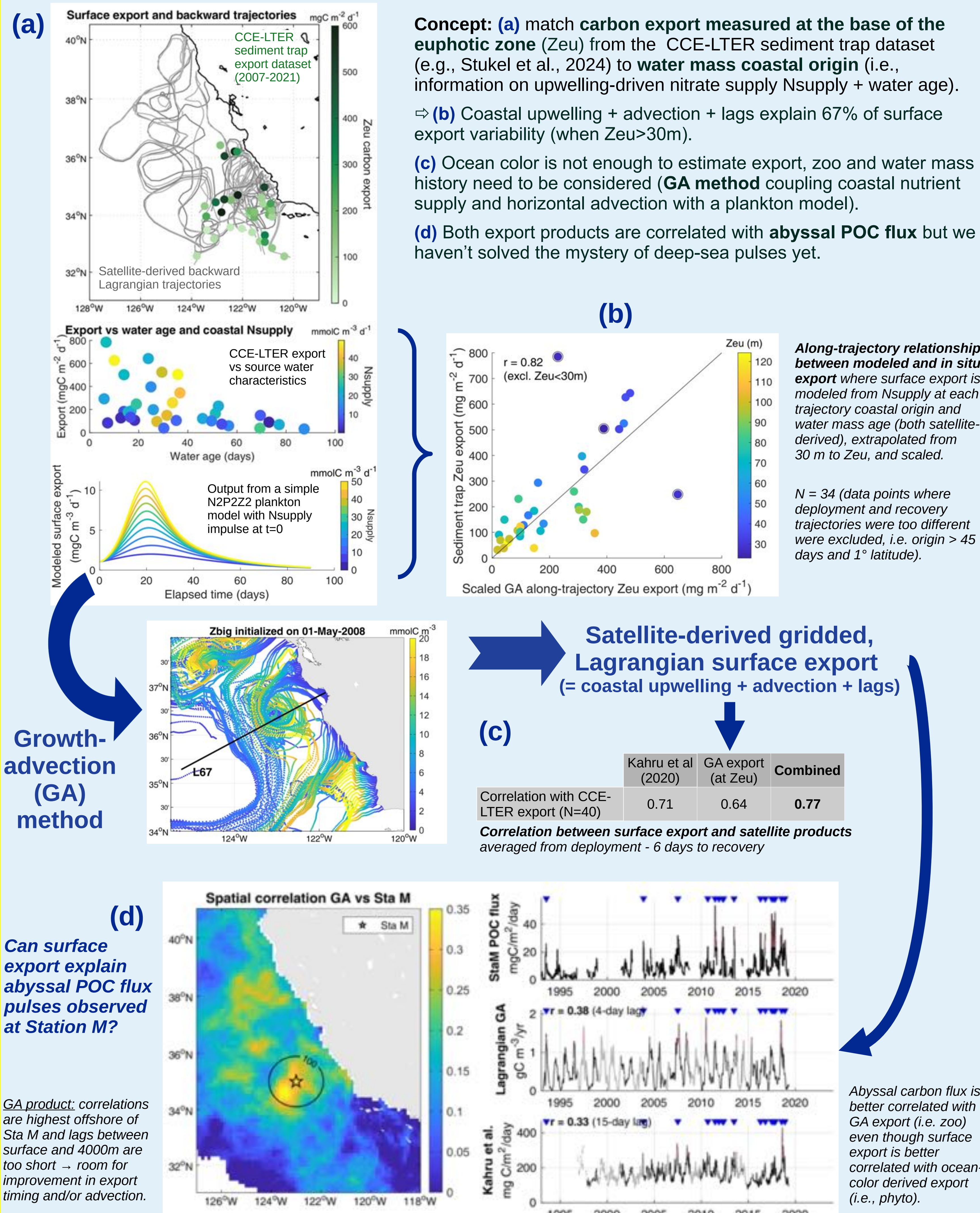
➢ Pathways:
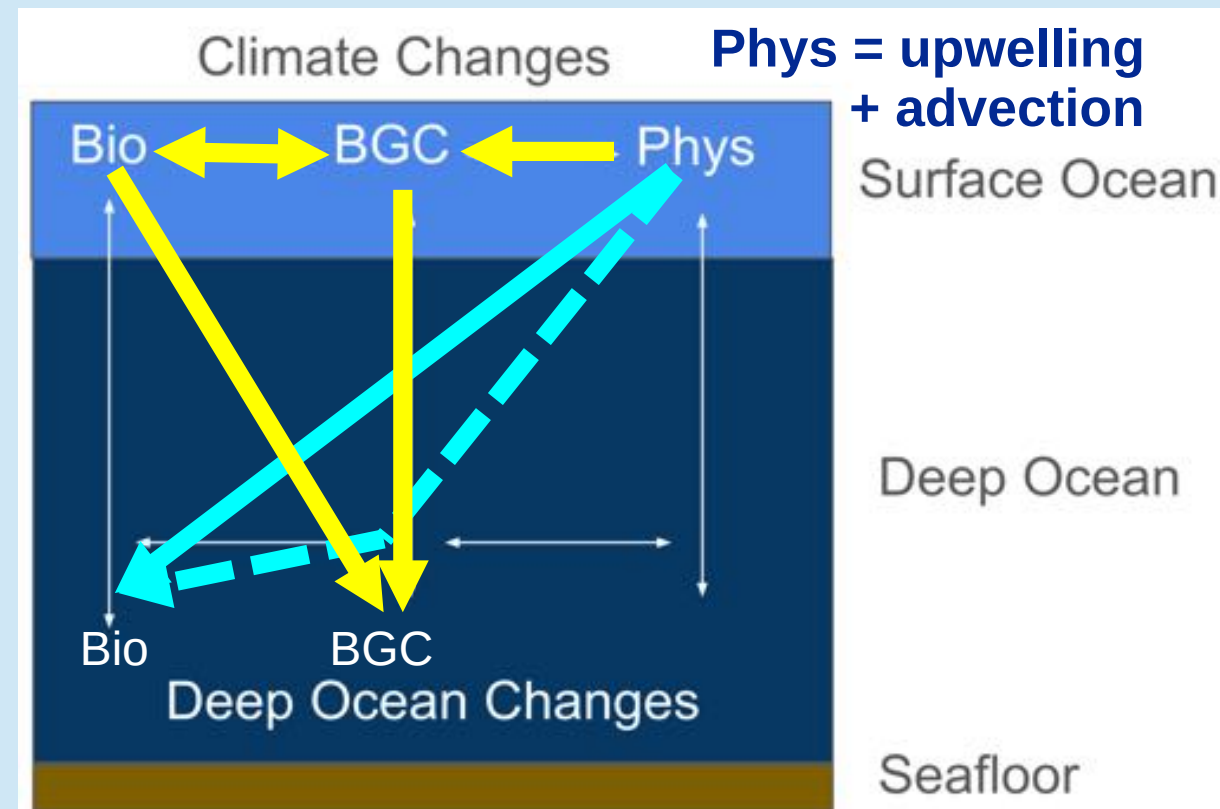
Context
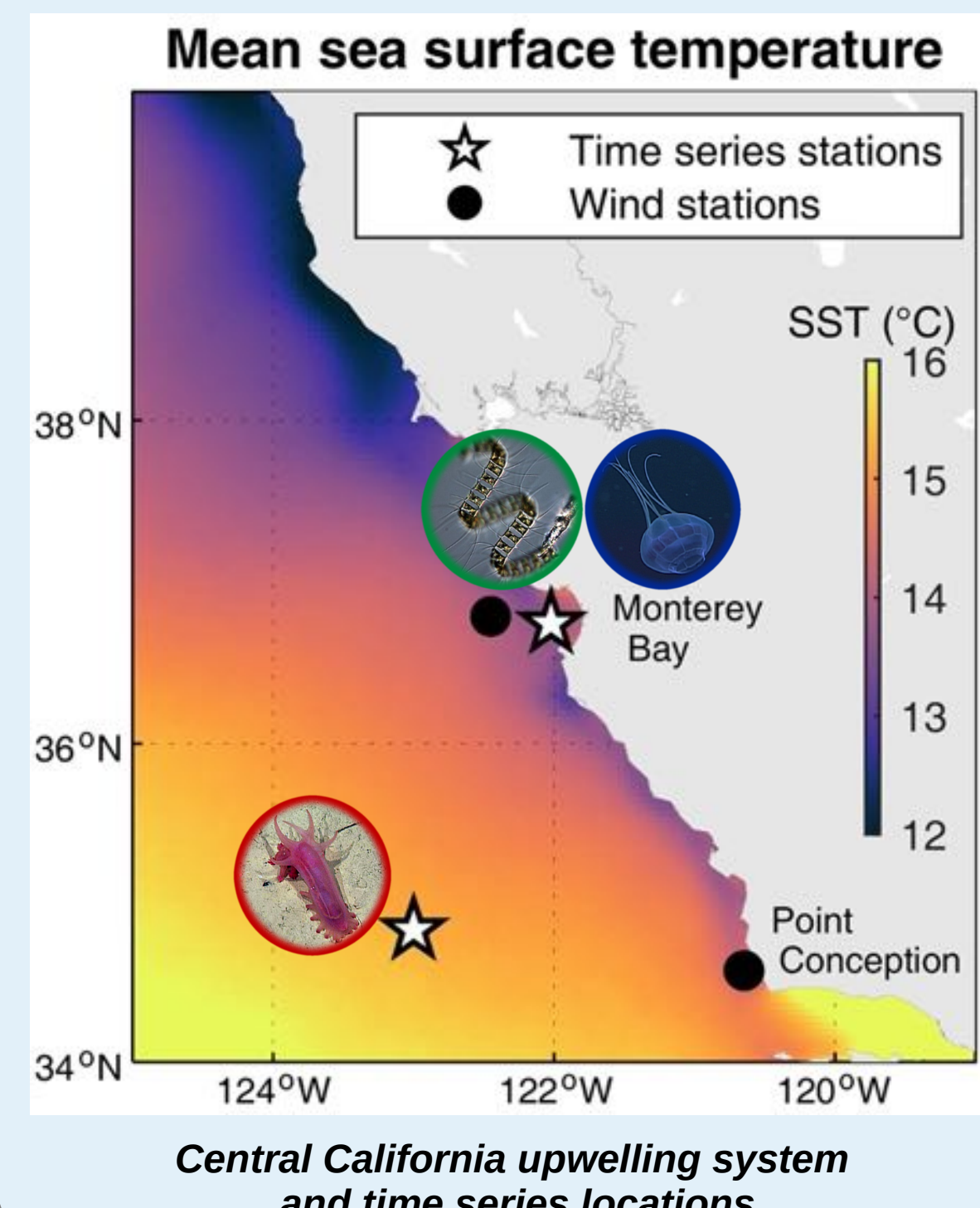
➢ California Current: upwelling-driven

➢ 3 long-term ecological time series in Monterey Bay (**surface**, **midwater**) and at Station M (**benthos**)

➢ Station M also includes abyssal POC flux (3400 m)

Central California upwelling system and time series locations

Conceptual schematic of interactions between climate and ecosystems in the region

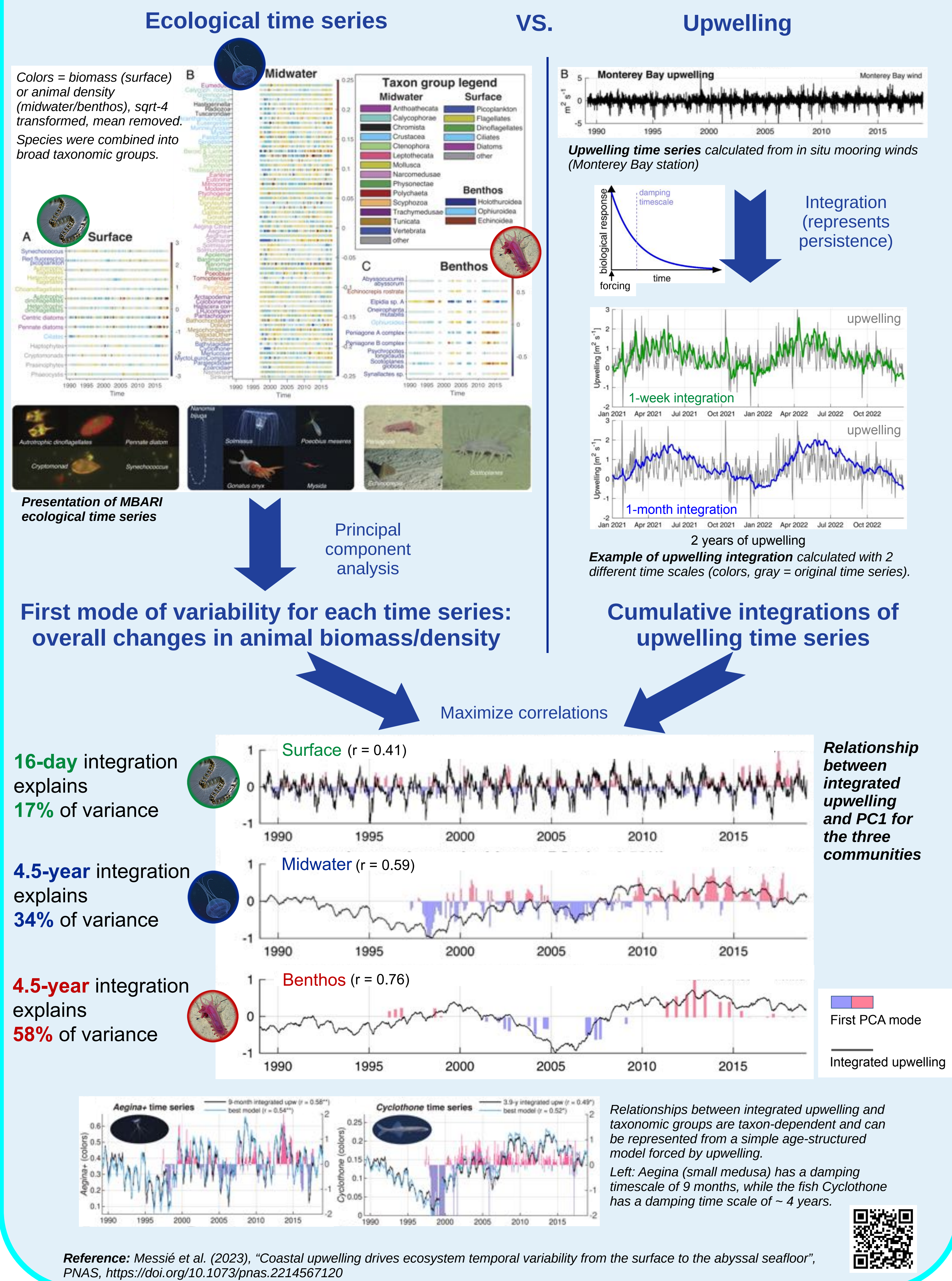⇨ **Connections between surface (upwelling) and deep-sea processes?**

(1) Upwelling is connected to surface carbon export and **abyssal POC flux**

⇨ Coastal upwelling and water mass history explain surface export
⇨ Export is likely a combination of local (phyto) and upstream (zoo) signals
⇨ Both ocean color and GA (zoo) products are linked to 4000-m carbon flux

(a)

Concept: (a) match **carbon export measured at the base of the euphotic zone** (Zeu) from the CCE-LTER sediment trap dataset (e.g., Stukel et al., 2024) to **water mass coastal origin** (i.e., information on upwelling-driven nitrate supply Nsupply + water age).

⇨ **(b)** Coastal upwelling + advection + lags explain 67% of surface export variability (when Zeu>30m).

(c) Ocean color is not enough to estimate export, zoo and water mass history need to be considered (**GA method** coupling coastal nutrient supply and horizontal advection with a plankton model).

(d) Both export products are correlated with **abyssal POC flux** but we haven't solved the mystery of deep-sea pulses yet.

(b)

Along-trajectory relationship between modeled and in situ export where surface export is modeled from Nsupply at each trajectory coastal origin and water mass age (both satellite-derived), extrapolated from 30 m to Zeu, and scaled.

N = 34 (data points where deployment and recovery trajectories were too different were excluded, i.e. origin > 45 days and 1° latitude).

Growth-advection (GA) method

Satellite-derived gridded, Lagrangian surface export
(= coastal upwelling + advection + lags)

(c)

	Kahru et al (2020)	GA export (at Zeu)	Combined
Correlation with CCE-LTER export (N=40)	0.71	0.64	**0.77**

Correlation between surface export and satellite products averaged from deployment - 6 days to recovery

(d)

Can surface export explain abyssal POC flux pulses observed at Station M?

GA product: correlations are highest offshore of Sta M and lags between surface and 4000m are too short → room for improvement in export timing and/or advection.

Abyssal carbon flux is better correlated with GA export (i.e. zoo) even though surface export is better correlated with ocean-color derived export (i.e. phyto).

GA reference: Messié et al. (2022), "Satellite-based Lagrangian model reveals how upwelling and oceanic circulation shape krill hotspots in the California Current System", Front Mar Sci, https://doi.org/10.3389/fmars.2022.835813
Kahru product reference: Kahru et al. (2020), https://doi.org/10.1016/j.dsr2.2019.104639
CCE-LTER sediment trap reference: Stukel et al. (2024), https://doi.org/10.1029/2023GB007994

We thank Mike Stukel for providing the CCE-LTER sediment trap dataset.

(2) Upwelling drives deep-sea **ecosystem temporal variability**

⇨ Coastal upwelling drives ecological variability down to the 4000m seafloor
⇨ Upwelling variability is damped on time scales linked to animal lifespans
⇨ The connection appears to be fast but the signal persists

Ecological time series VS. **Upwelling**

Colors = biomass (surface) or animal density (midwater/benthos), sqrt-4 transformed, mean removed. Species were combined into broad taxonomic groups.

Taxon group legend

Presentation of MBARI ecological time series

Upwelling time series calculated from in situ mooring winds (Monterey Bay station)

Integration (represents persistence)

Example of upwelling integration calculated with 2 different time scales (colors, gray = original time series).

Principal component analysis

First mode of variability for each time series: overall changes in animal biomass/density

Cumulative integrations of upwelling time series

Maximize correlations

16-day integration explains **17%** of variance

4.5-year integration explains **34%** of variance

4.5-year integration explains **58%** of variance

Relationship between integrated upwelling and PC1 for the three communities

First PCA mode
Integrated upwelling

*Relationships between integrated upwelling and taxonomic groups are taxon-dependent and can be represented from a simple age-structured model forced by upwelling.
Left: Aegina (small medusa) has a damping timescale of 9 months, while the fish Cyclothone has a damping time scale of ~ 4 years.*

Reference: Messié et al. (2023), "Coastal upwelling drives ecosystem temporal variability from the surface to the abyssal seafloor", PNAS, https://doi.org/10.1073/pnas.2214567120