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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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INVESTIGATIONS OF EFFECTS OF LOCAL ANTHROPOGENIC NUTRIENT INPUTS ON ACIDIFICATION AND HYPOXIA IN THE SOUTHERN CALIFORNIA BIGHT

SCCWRP Established 1969

THE UNIVERSITY OF CALIFORNIA · LET THERE BE LIGHT · UCLA

UNIVERSITY OF WASHINGTON · LVX SIT · 1861

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION · PMEL · PACIFIC MARINE ENVIRONMENTAL LABORATORY

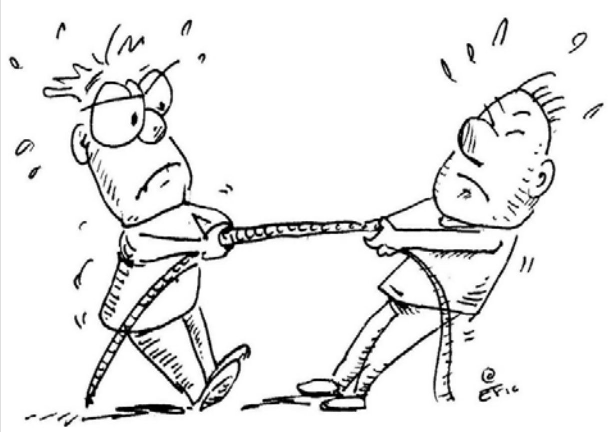
WEBINAR: September 03, 2019

Fayçal Kessouri

With James McWilliams, Martha Sutula, Daniele Bianchi, Curtis Deutsch, Richard Feely, Karen McLaughlin, Lionel Renault, Steve Weisberg and many science partners

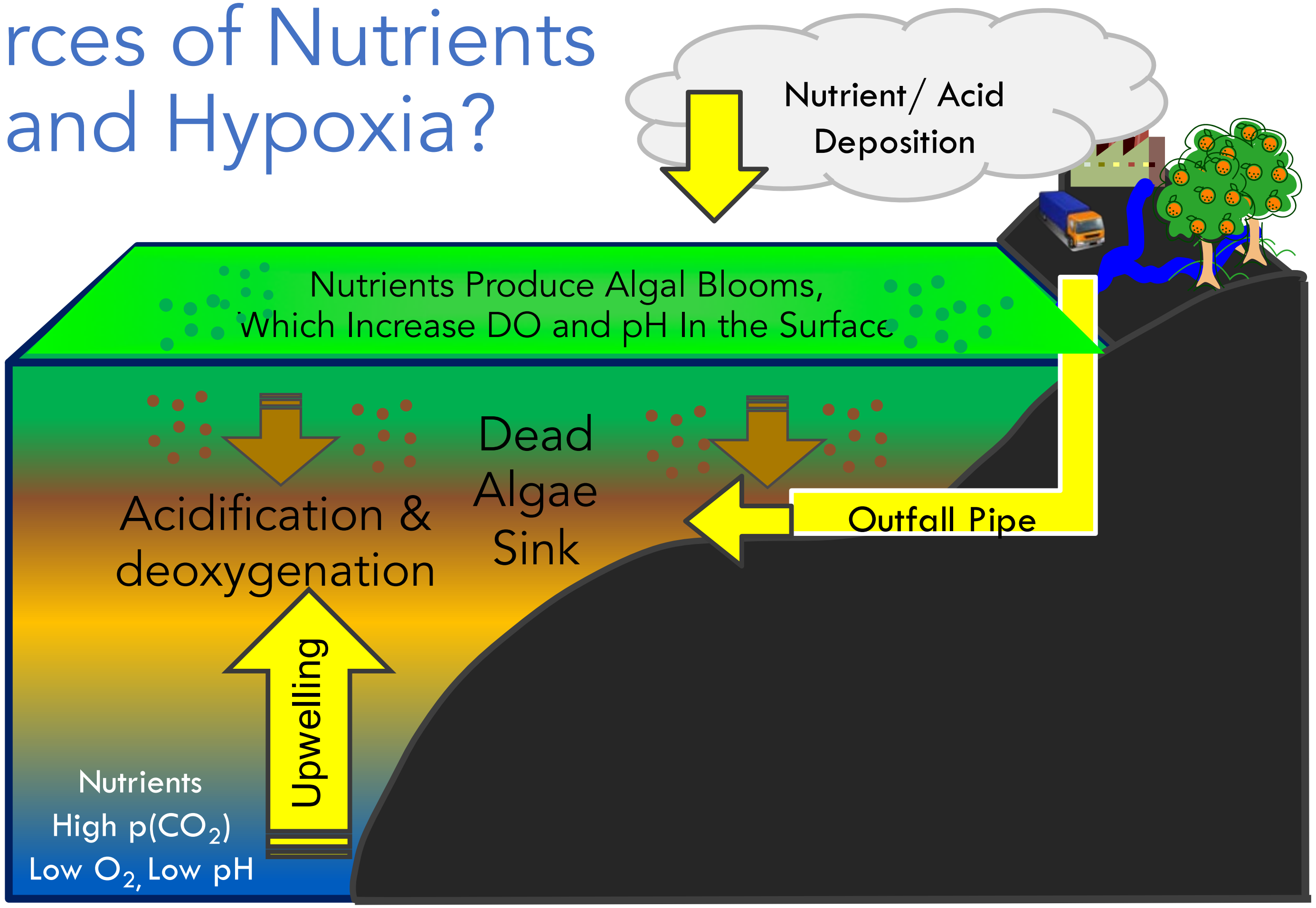
Are Local Anthropogenic Sources of Nutrients Exacerbating Acidification and Hypoxia?

Local anthropogenic inputs can exacerbate global drivers, potentially pushing Dissolved O_2 and pH to ecological tipping-points



<u>Two Opposing Views:</u>

California coastal waters are dominated by upwelling, therefore anthropogenic nutrients are not a primary driver



We need validated mechanistic numerical ocean models to disentangle

- Natural variability (upwelling)
- Global climate change
- [local] anthropogenic nutrient and organic matter inputs

Atmospheric forcing
- Weather Research Forecast -

Ocean circulations
- Regional Oceanic Modeling System -

Biogeochemical Elemental Cycling

Zooplankton

Phytoplankton

Nutrients

Iron
Silicate
Phosphate
Nitrate
Nitrite
Ammonium

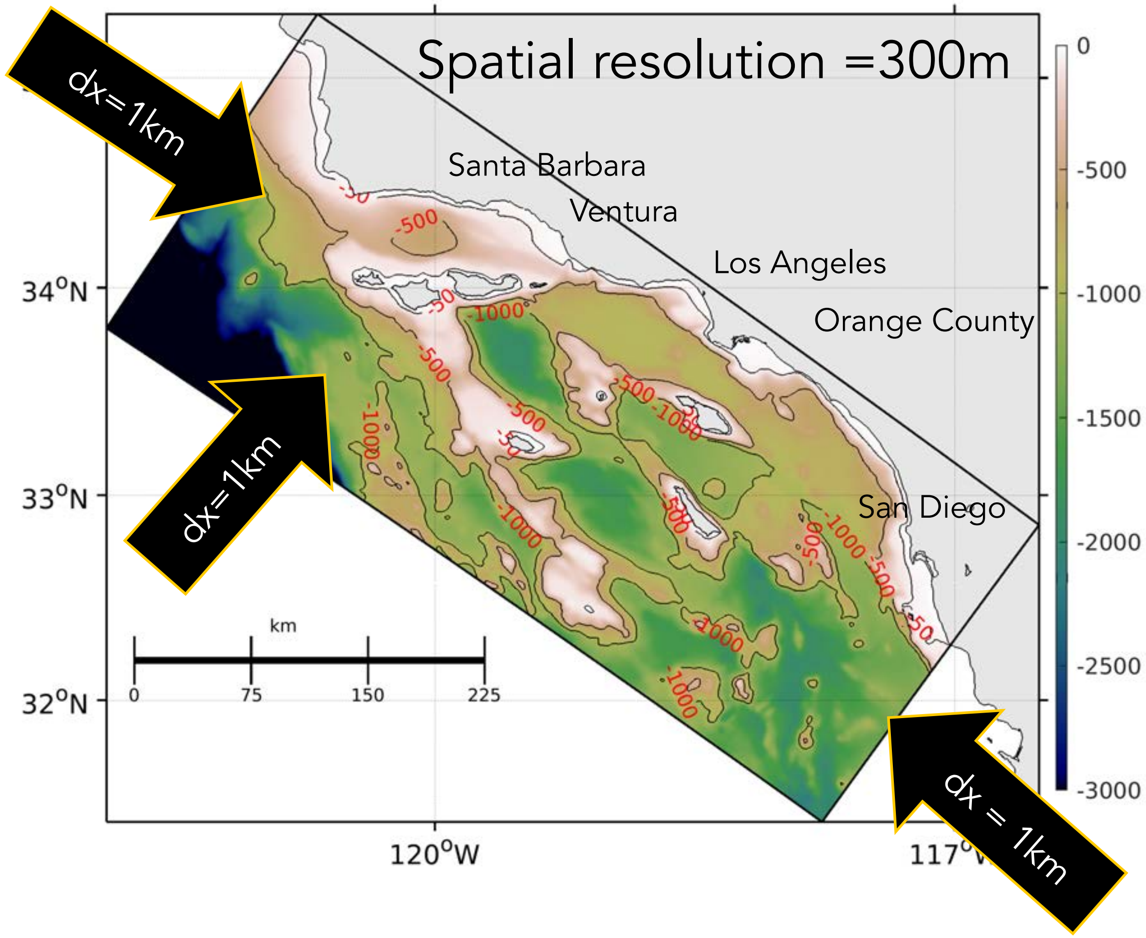
Dissolved Oxygen

pH

Organic matter

Key Attributes of ROM-BEC Allow Us to Investigate the Effects of Natural Versus Anthropogenic Nutrients on Ocean Biogeochemistry and Lower Ecosystem

Bathymetry (m)



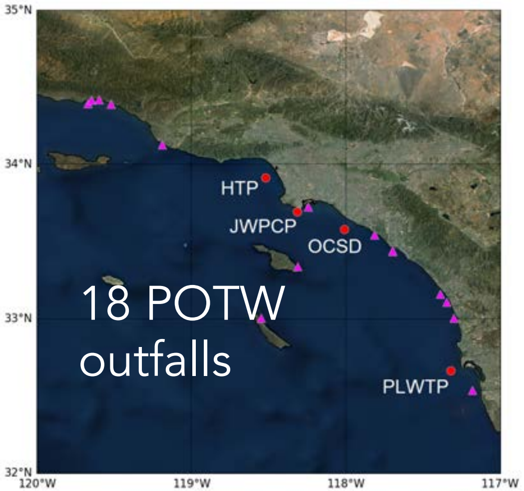
In collaboration with Partners We Compiled Daily Data on Land-based And Atmospheric Sources of Nutrients, Organic Matter and Freshwater to Used in Model Simulations (Anthropogenic And Natural)

River runoff

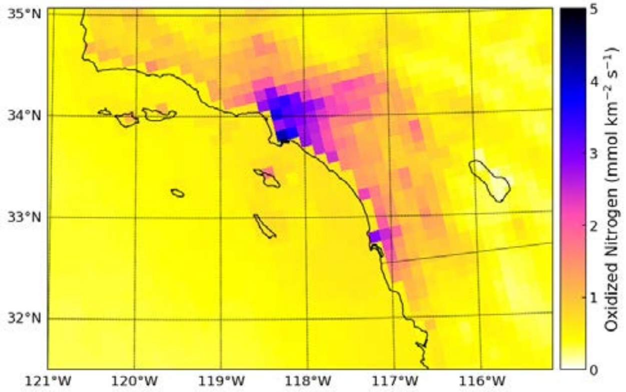
(natural + anthropogenic)

POTW ocean outfalls

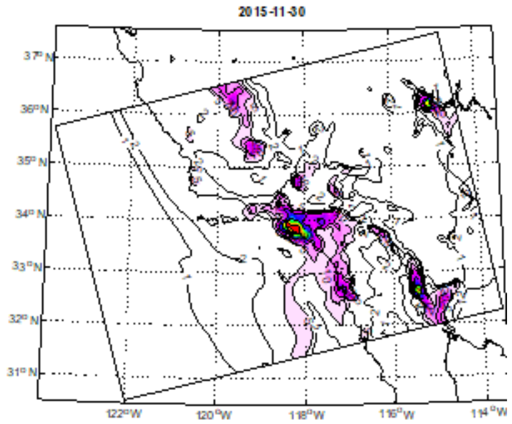
(only anthropogenic)



Modeled wet and dry deposition (natural and anthropogenic; EPA community multiscale air quality model



Modeled local atmospheric CO_2 air sea exchange (anthropogenic) (Feng et al)



SCB Stakeholders previously agreed on set of two scenarios to assess effects of local anthropogenic inputs

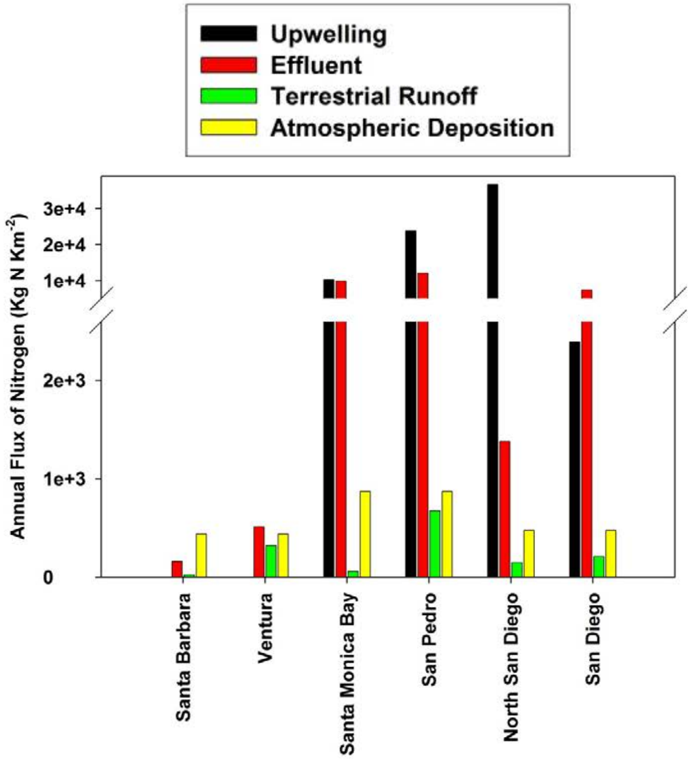
a) Ocean with no atmospheric or land-based inputs

We call this "no forcing"

b) Ocean with atmospheric deposition and land-based input

We call this "anthropogenic forcing"

Early Modeling Studies (Bight '08) Showed Us that Outfall N Contributes Over 70% of All Land-based and Atmospheric Sources

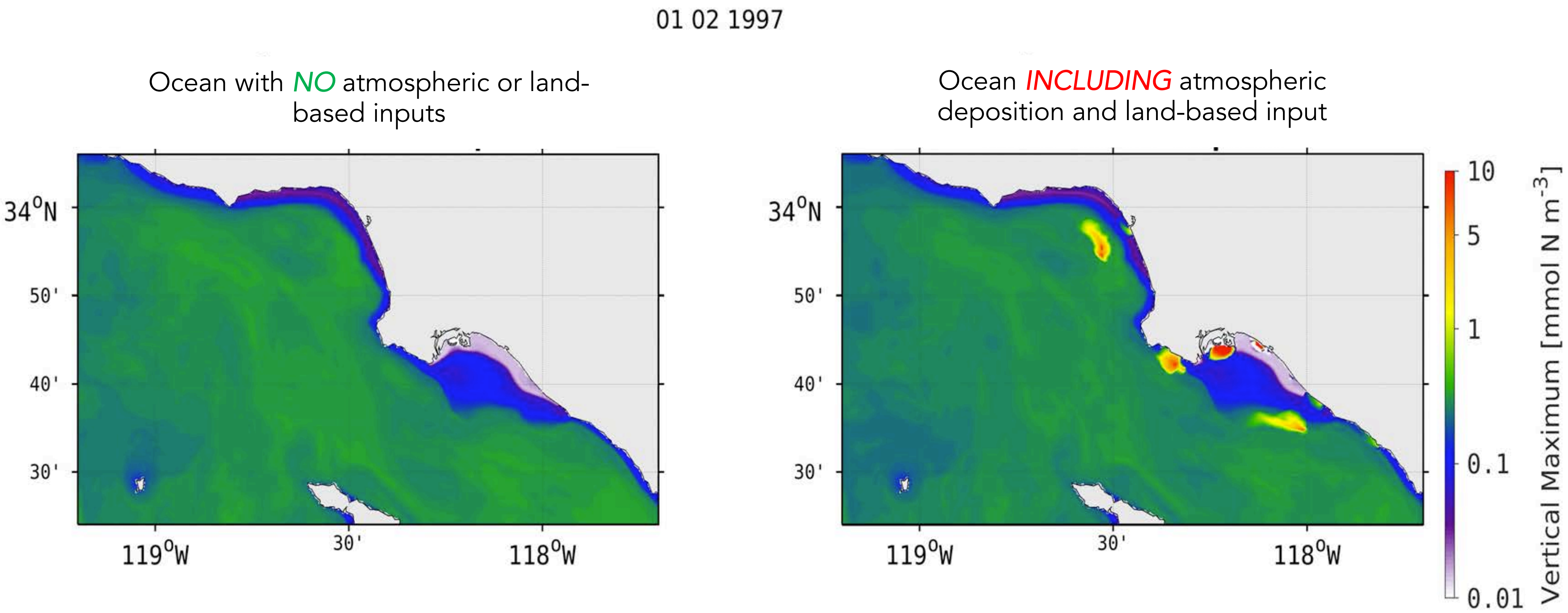


Howard et al., 2014

This Spring, A Set of Scenarios Were Completed (1997-2000) to Validate ROMS-BEC for This Application and Conduct An Initial Assessment of Effects

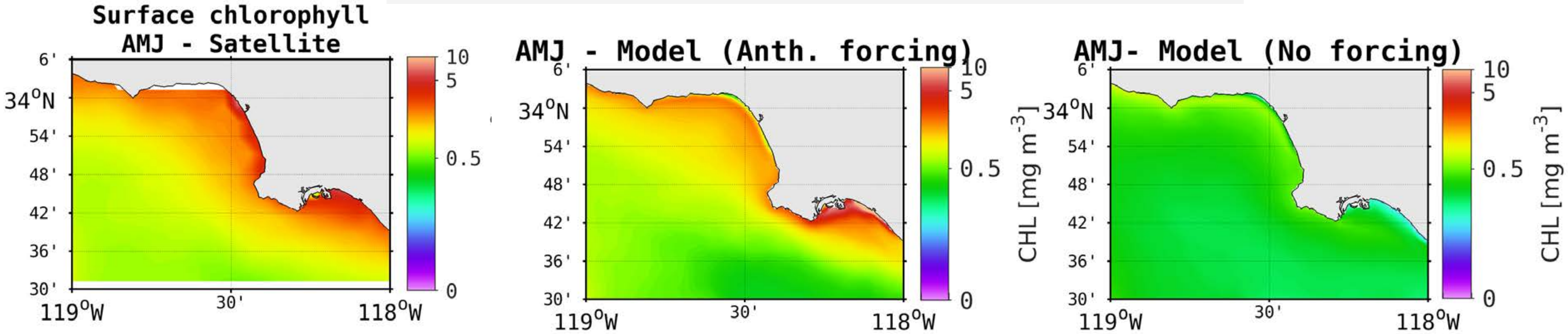
- We made a preliminary estimate of “effect” of anthropogenic nutrients on chlorophyll-a, O_2 & pH
- We validated the model against available observations, focusing on “anthropogenic” gradients
- We discussed these findings at a recent SCB Stakeholders Advisory Group meeting and identified next steps

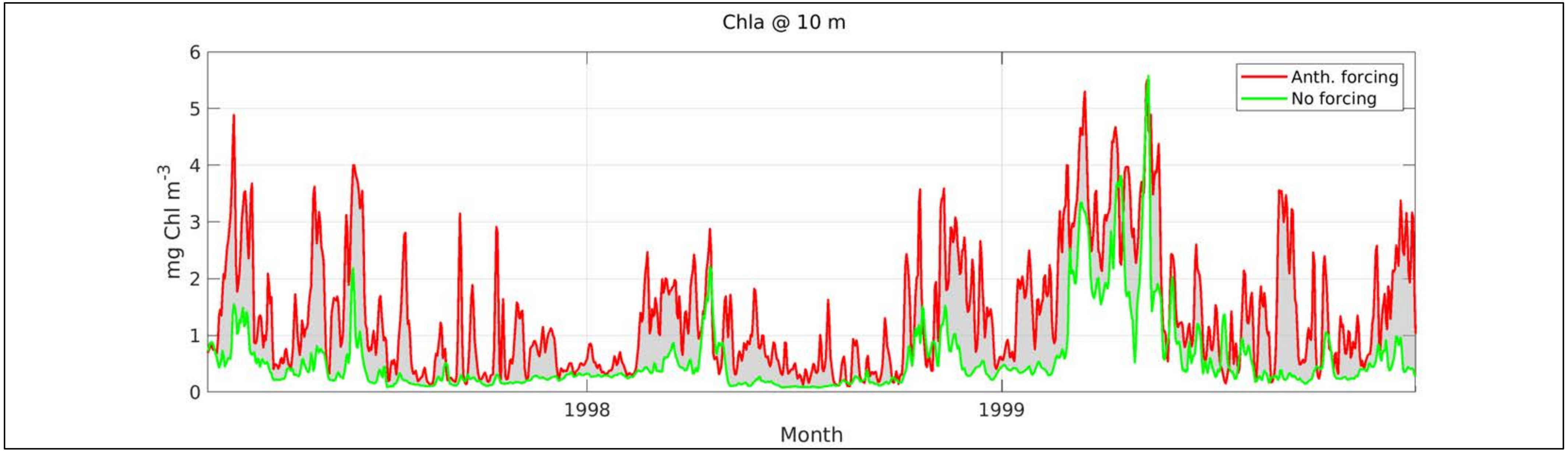
Nitrogen Is Widely Dispersed By Ocean Currents Far From Sources



Model Predict Substantial Increase In Algal Blooms

AMJ = Spring: April, May, June --- (Average 1998-2000)

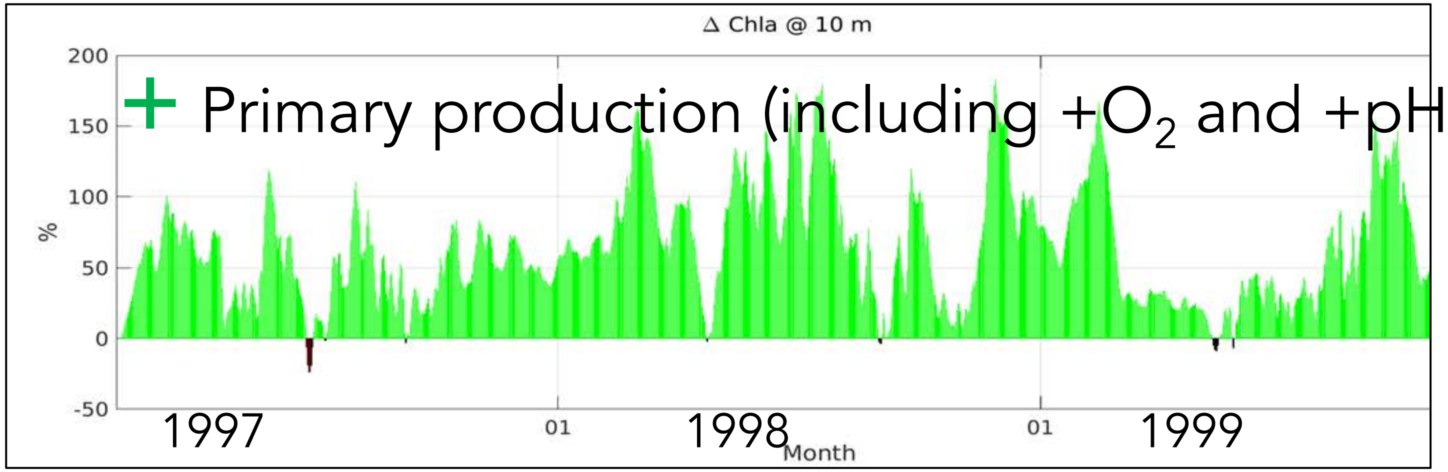




Increased Productivity Increases O_2 And pH At The Surface But Reduces O_2 and pH At Depth

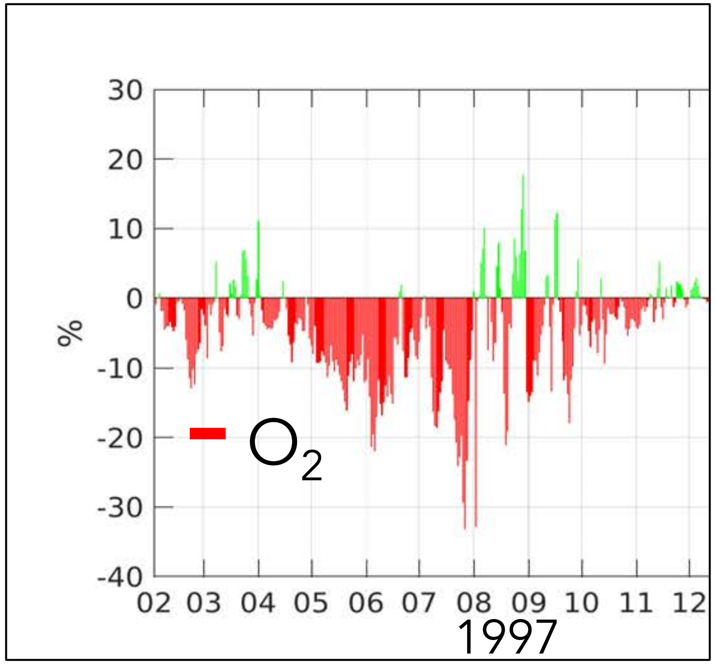
0 m

Chl-a at the surface

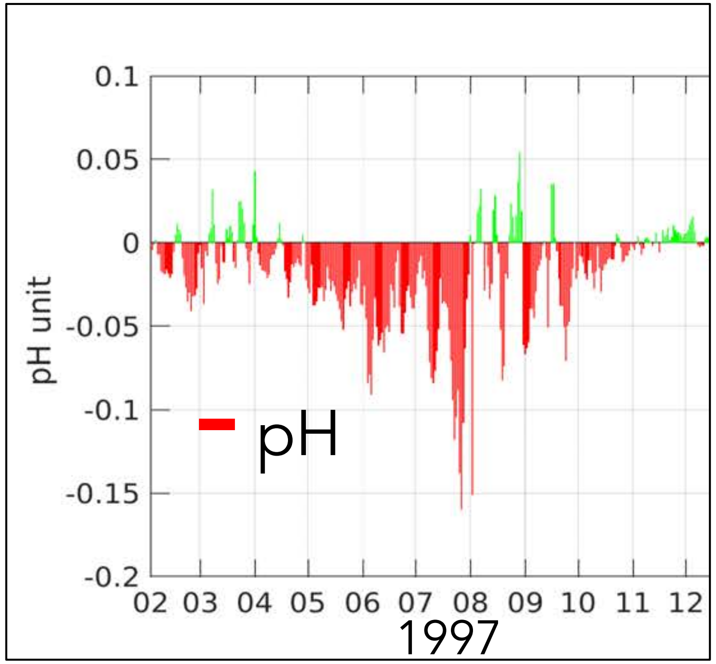


Oxygen and pH at 50m

O_2



pH



Bottom

Model Validation

Model Faithfully Reproduces Anthropogenically-Enhanced Gradients in Chl-a, O_2 and pH Found In Ocean Observations At Appropriate Scales

Temporal Scales

✓ Seasonal

- Model is capturing a well mixed water column in winter, and stratification in summer

Spatial Scales

✓ **Vertical scale** (with depth or density)

- Appropriate change with depth relative to "mixed layer"

✓ Alongshore and Cross-shelf

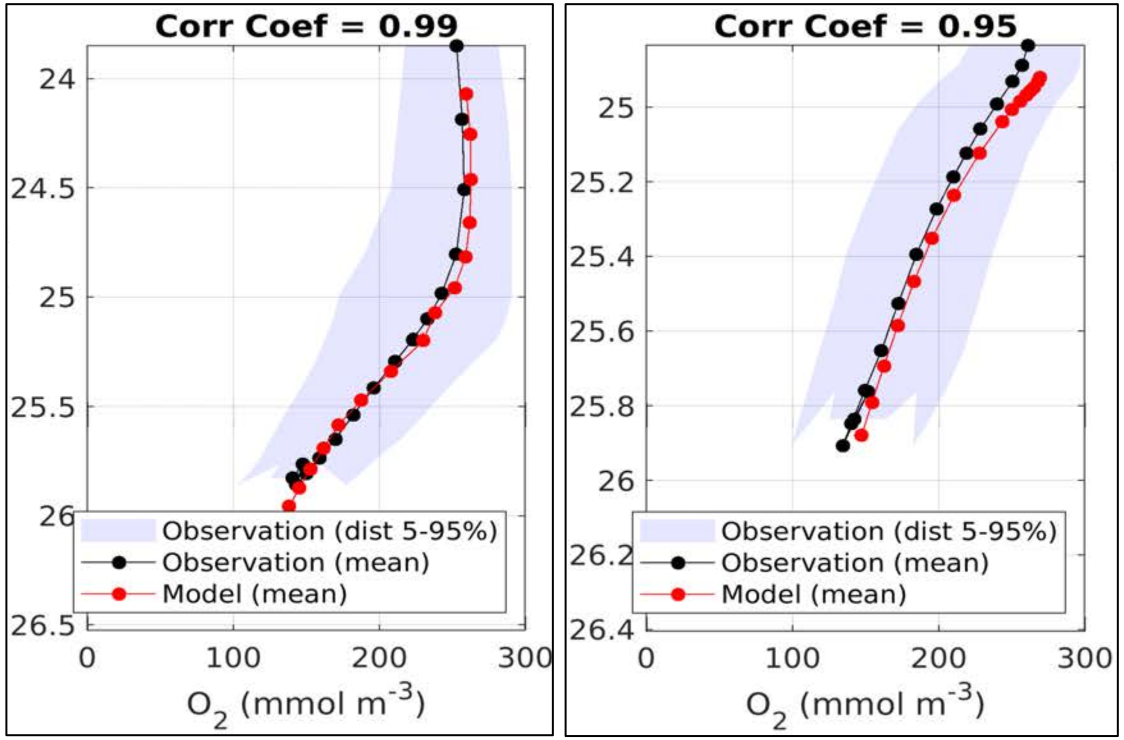
- E.g. Model captures intensification of anthropogenic gradients closer to shore

✓ Plume scale

- Effects are intensified near outfalls and rivers mouths

Oxygen profiles

Summer Winter



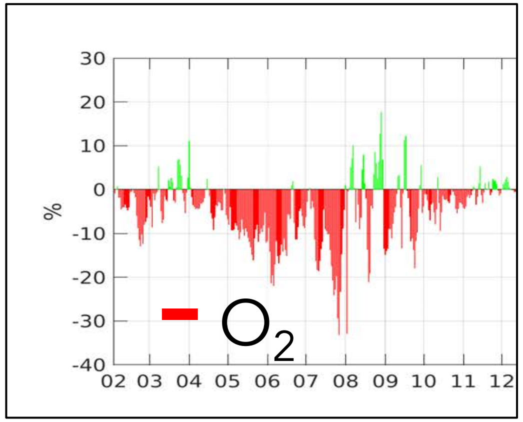
Are These Differences Significant Enough To Warrant Management Attention?

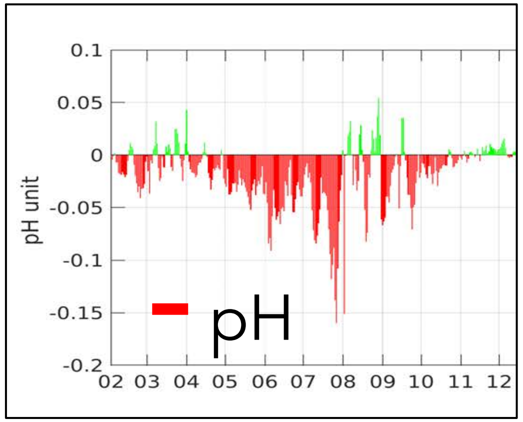
To Initiate Discussions Among stakeholders:
We Applied Thresholds From Two Approaches Reflected in the California Ocean Plan Water Quality Standards

1) Numeric O_2 and pH Objectives

Dissolved O_2 shall not be depressed >10 % from that which occurs naturally, as a result of discharge of oxygen demanding waste.

pH shall not be changed > than 0.2 units from that which occurs naturally.

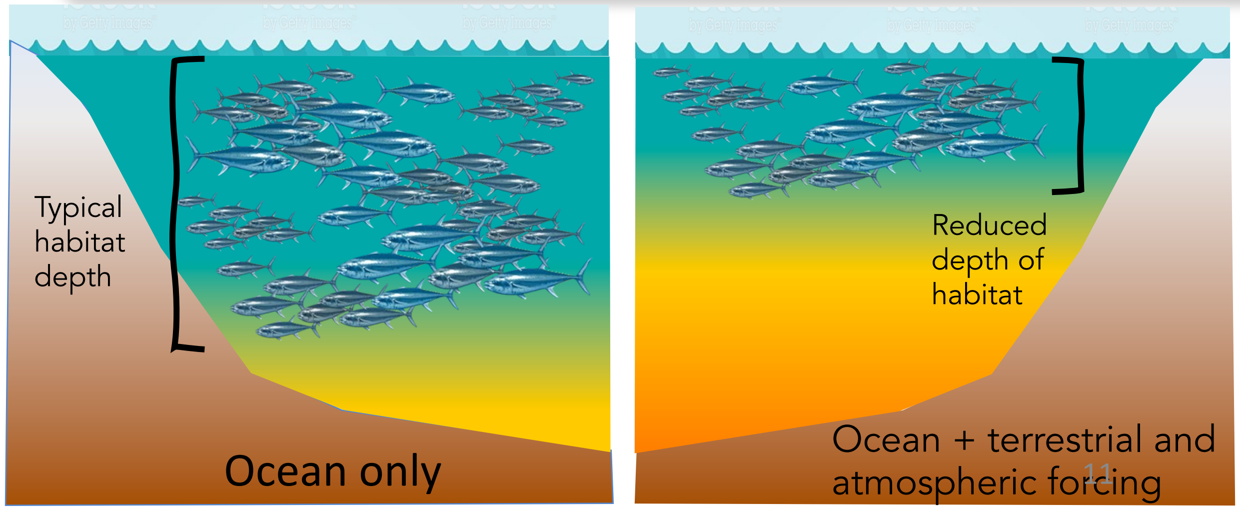




2) Narrative Biological Integrity Objectives

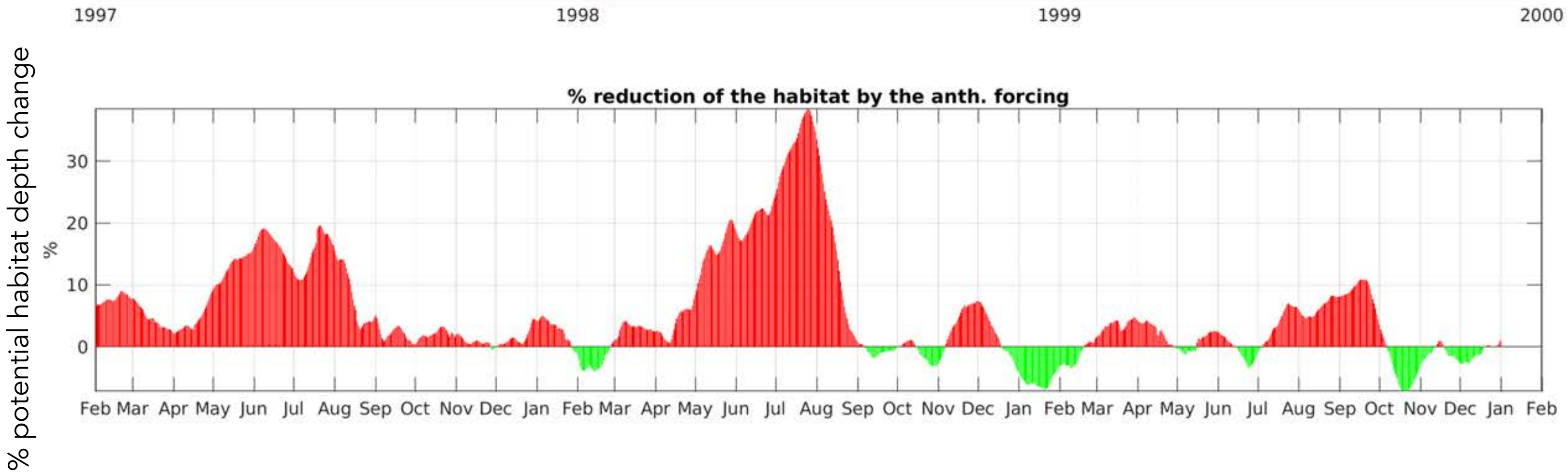
Nutrient materials shall not cause **objectionable aquatic growths or degrade indigenous biota**

Here we use recent science on biologically relevant thresholds for DO_2 and pH to estimate potential habitat compression for selected marine taxa



We Found Excursions Of Thresholds For Both Approaches: O_2 % change and biological effects

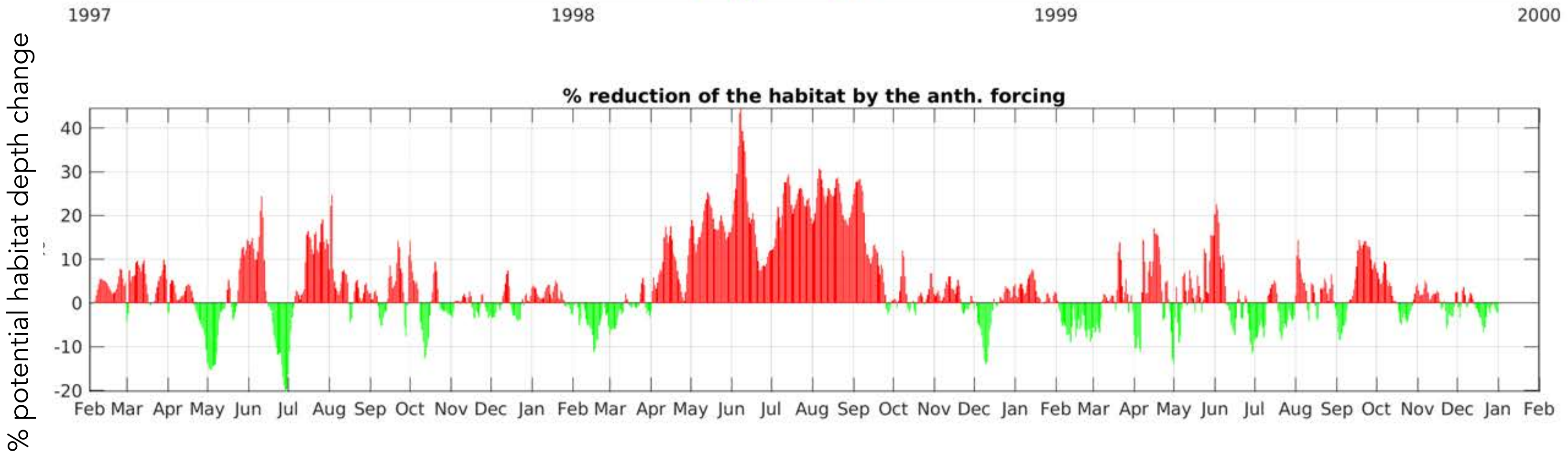
e.g. Santa Monica Bay Subregion, Anchovy Aerobic Habitat Change



Northern Anchovy (0-200 m)

Deutsch et al. 2015, Howard et al. In review

Santa Barbara Subregion, Pteropod Reproductive Endpoint



Pteropods (0-200 m)

Bednarsek et al. (2019)

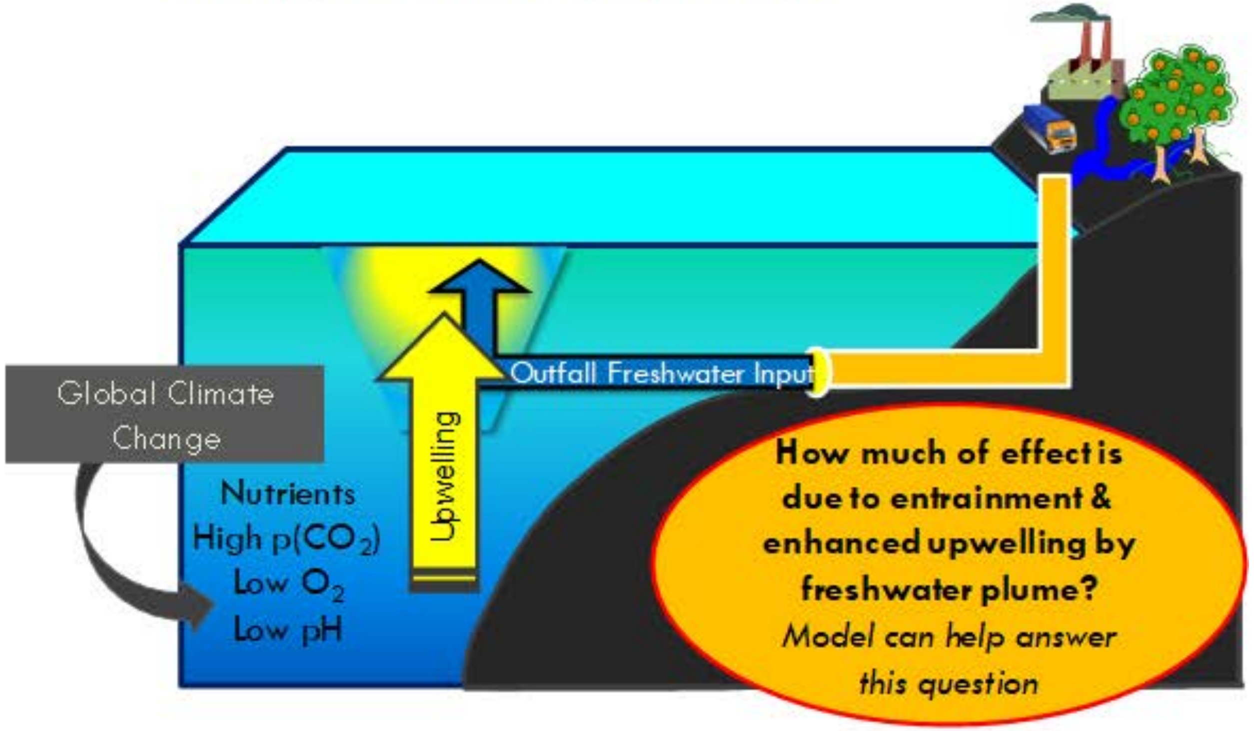
While Excursions of Thresholds Are Found, The Management Significance is Still Under Discussion

The Devil is in the Details: Lots of Decisions are Required that Can Affect the "Significance" of Effect

Interpreting Ocean Plan Numeric Objectives

- Scale of assessment – what depth range? What horizontal spatial scale? What time period?
- Decisions on how to aggregate data
- Individual effect of a single source or cumulative impact?
- Effect of freshwater only versus nutrients and organic matter?

What is the contribution of freshwater entrainment of deep waters alone?



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Interpreting Narrative Biological Objectives

Same issues of ocean plan standards, plus

- Which species/habitats to choose
- How to apply thresholds and what is considered significant?
  - Best metric of change? Absolute depth change, percent change?
  - Extent and severity of effect requires additional interpretation and consensus among biologists

We need consensus on the interpretation approach

Scientists and SCB Stakeholders Are Fully Engaged In Moving Discussions Forward

Two subcommittees were created to shape the future work plan

1) Interpretation Approach, led by Katherine Walsh, State Water Board

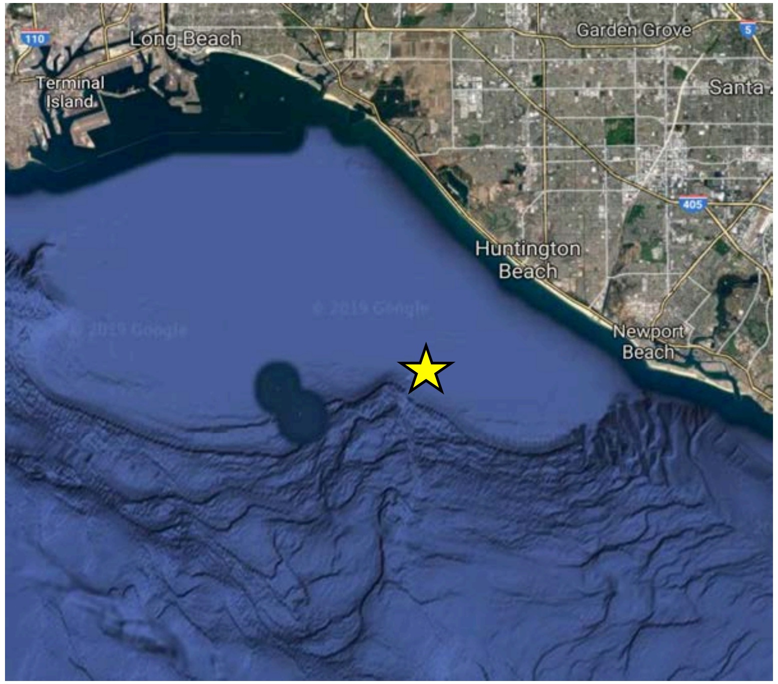
- Develop an approach to interpret "impacts" for the existing (and new) model runs

2) Validation and new model scenarios, led by George Robertson Orange County Sanitation District

- Complete validation to the stakeholders' satisfaction
- Run additional model scenarios that address the most prominent management questions (e.g. attribution of individual sources, climate change impacts, etc.)

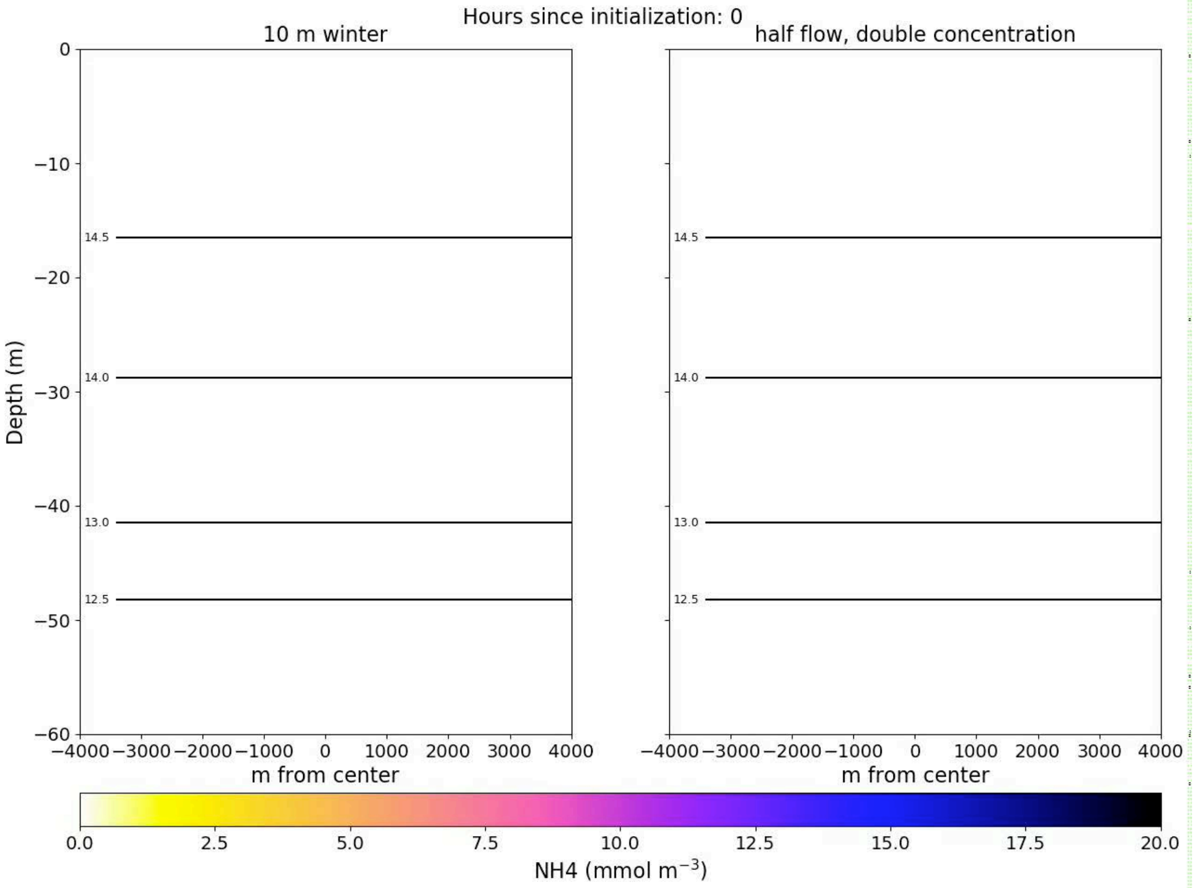
Investigations of Impacts of Wastewater Recycling on Plume Buoyancy and Environmental Effects is Among the Leading Management Scenarios of Interest

Leveraged by an OC Sanitation District-sponsored Modeling Project to Investigate the Environmental Impact of Wastewater Recycling



Investigating Plume Dispersion After Water Recycling

Huntington Beach (Orange County)



Sponsored by *Orange County Sanitation District* - Animation by: Minna Ho

We've Formed New Collaborations with Scientists and Stakeholders to Conduct Similar Investigations in Central Coast

Modeling anthropogenic inputs from San Francisco Bay and Monterey coast

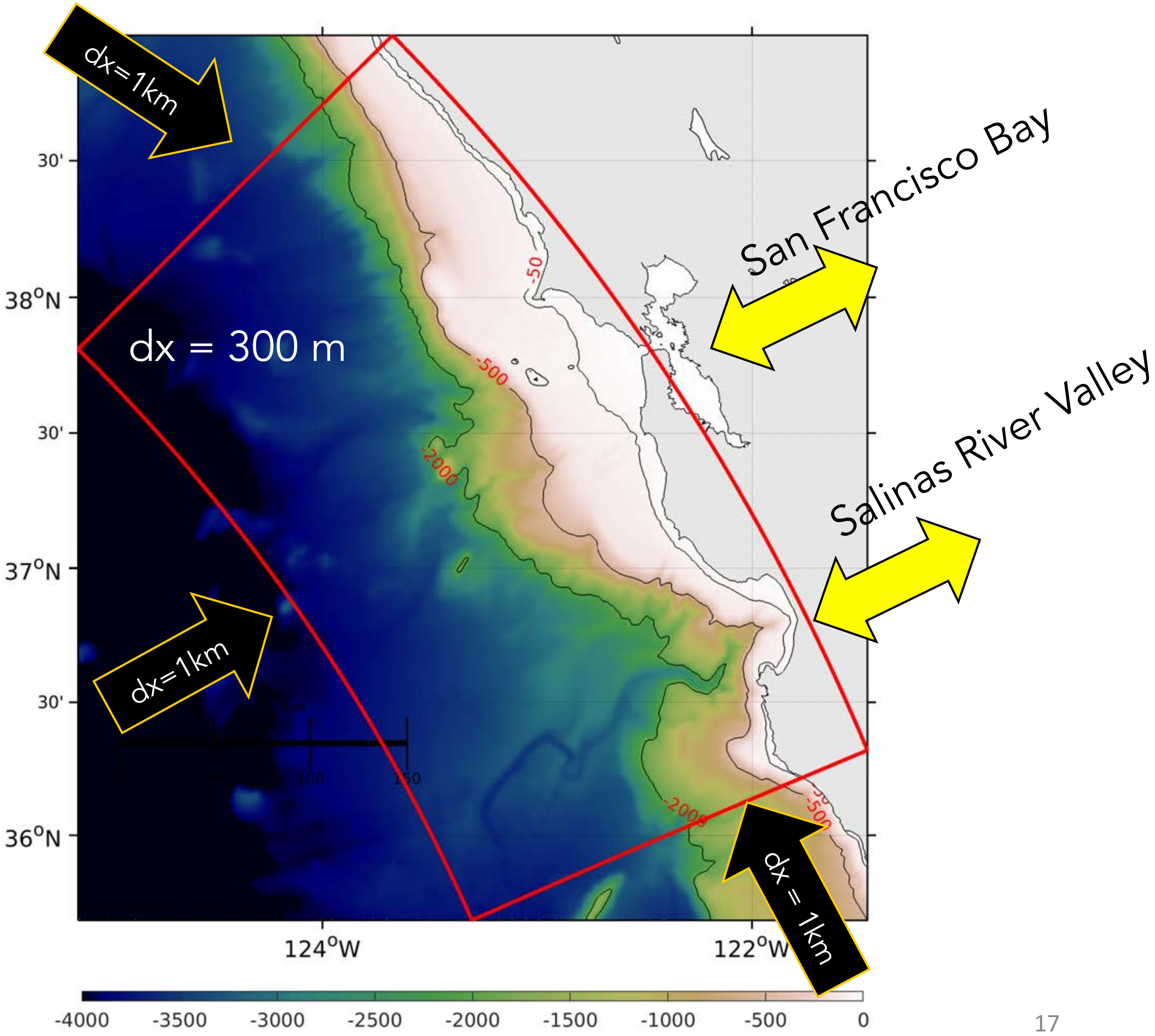
Collaborative Project with SF Bay Nutrient Management Strategy and SFEI (Senn et al.)

UC Santa Cruz (Edwards et al.,)

And other Regional Partners

Elkhorn Slough NERR

Central Coast Water Board



Questions, discussions, suggestions, collaboration?

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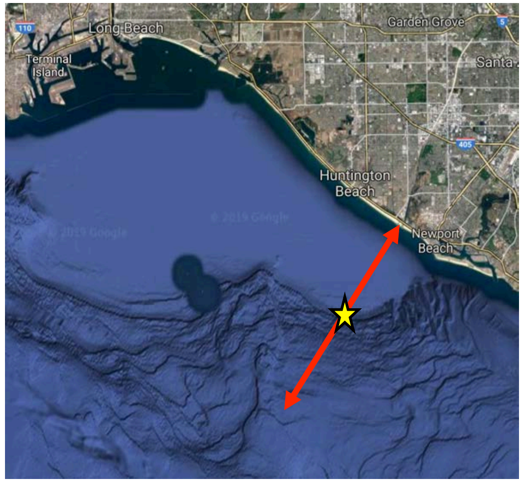
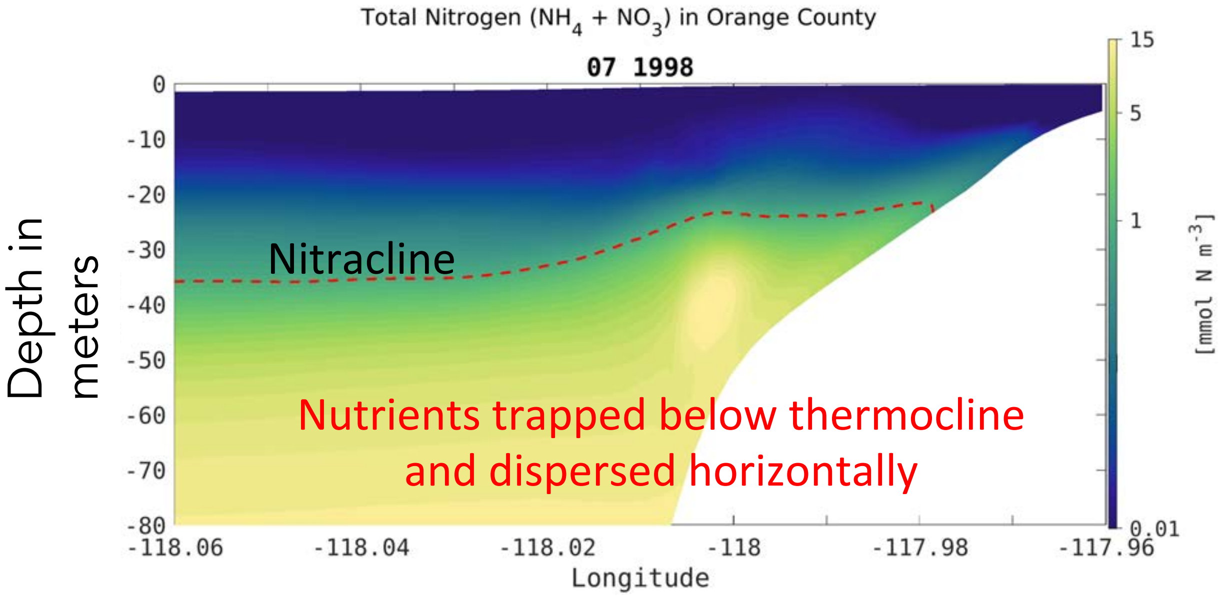
Additional slides

Outfall nitrogen mixes with upwelling with strong seasonality



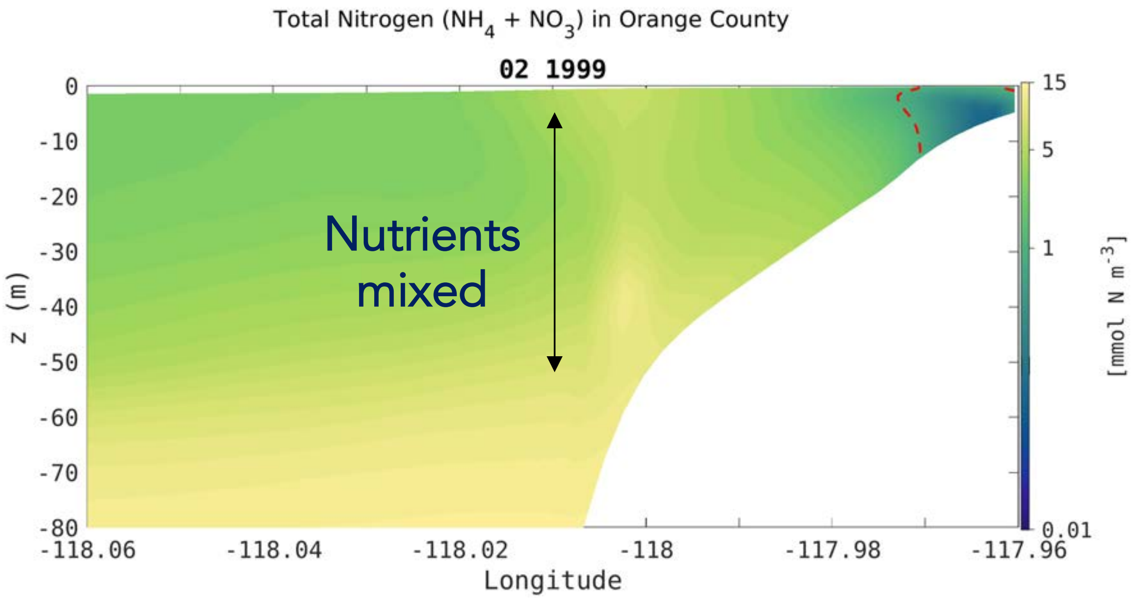
E.g. At Huntington Beach (Orange County)

Summer



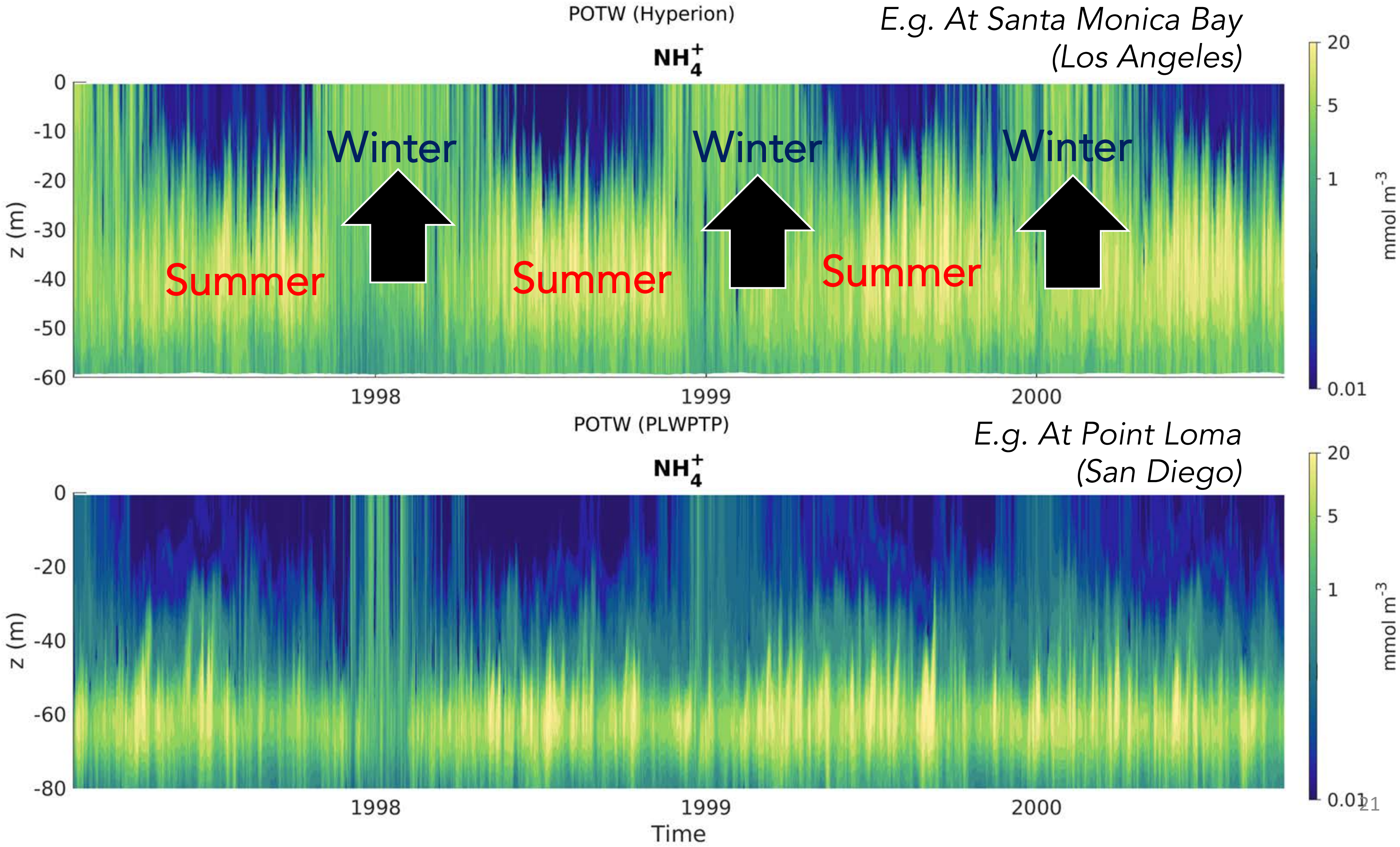
Offshore Coast

This situation is recurrent in winter



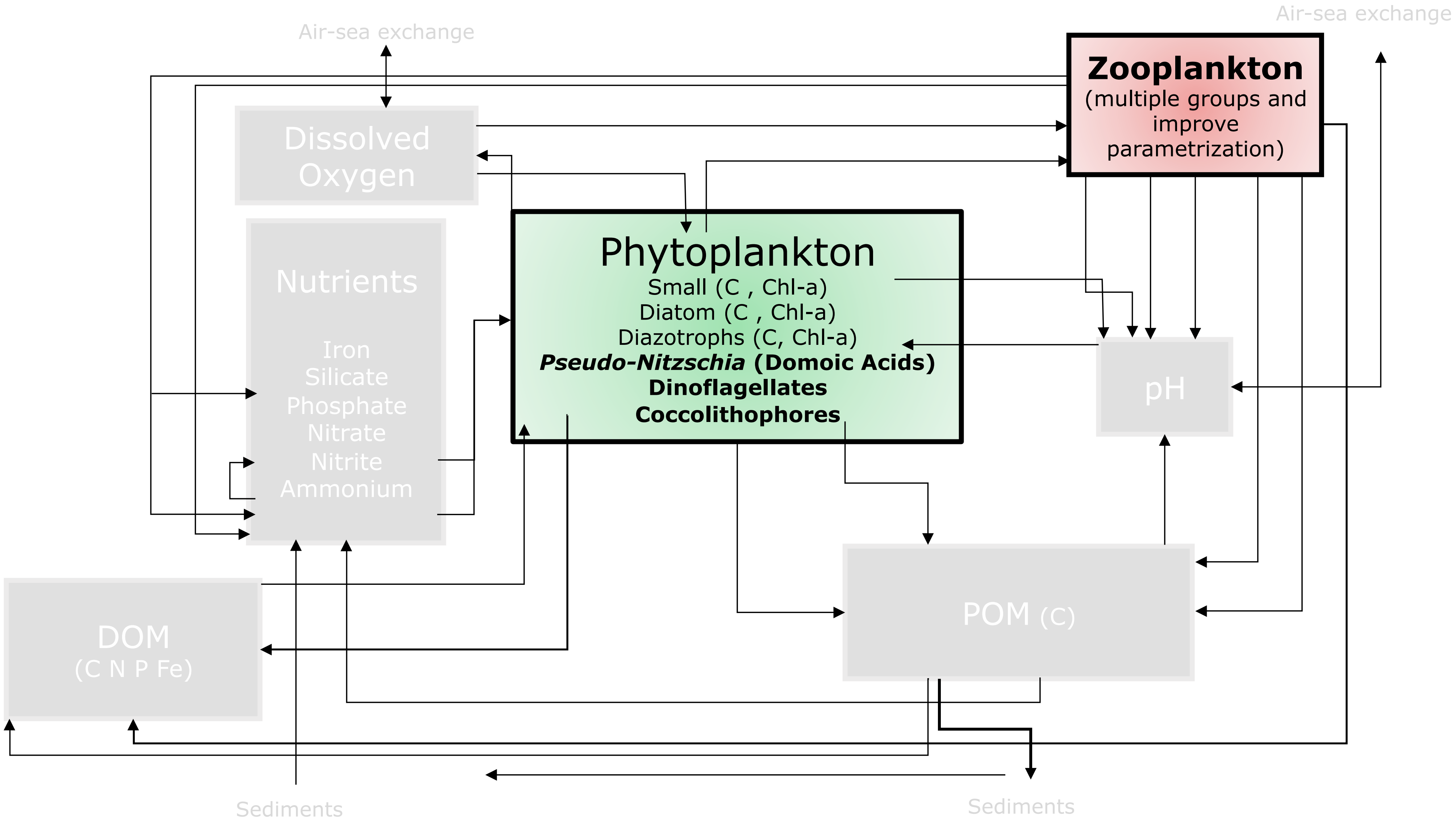
Offshore Coast

Intensity Of Mixing Varies Between Regions

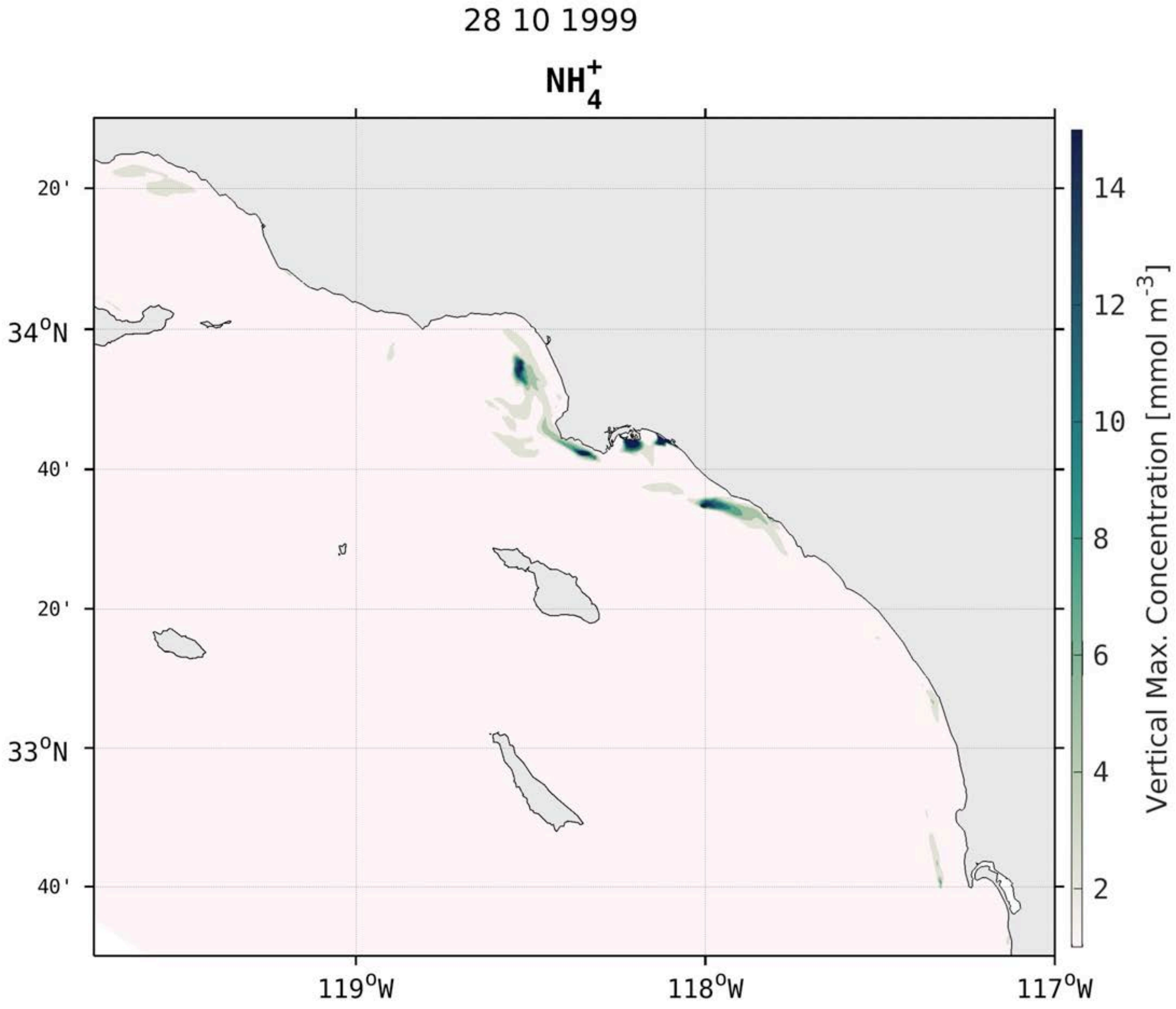


HABS in Southern California

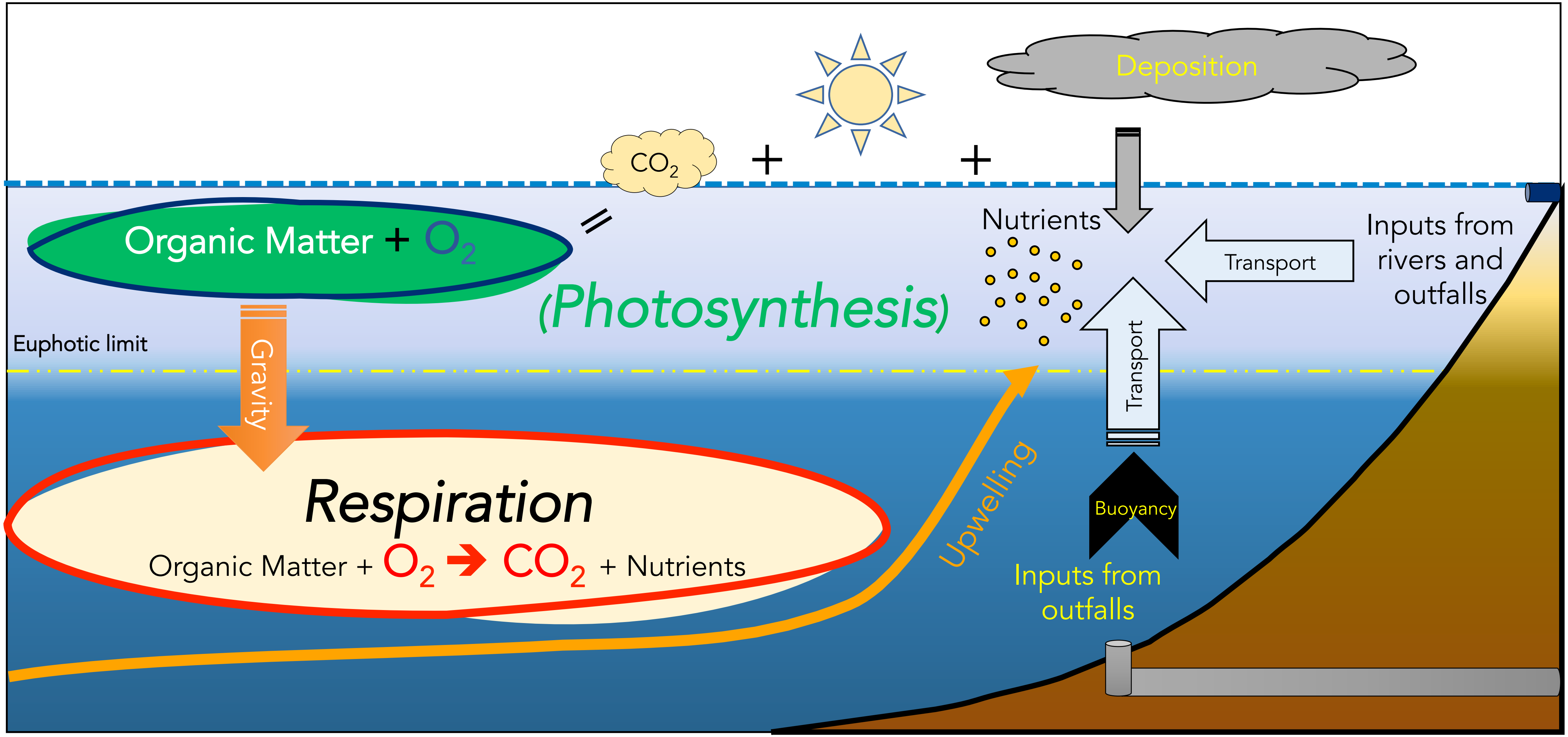
UCLA (Bianchi et al) – SCRIPPS (Anderson et al) – UCI (Kudela et al) – SCCWRP (Sutula et al) – UW (Deutsch et al)



Nutrients disperse horizontally far from the sources



Algal Photosynthesis Produces Oxygen In The Euphotic Zone
Respiration Consumes Oxygen And Produces CO_2 At Depth



Metric:
Which one matters?

Difference in dissolved O_2 and pH caused by the anthropogenic nutrients loads

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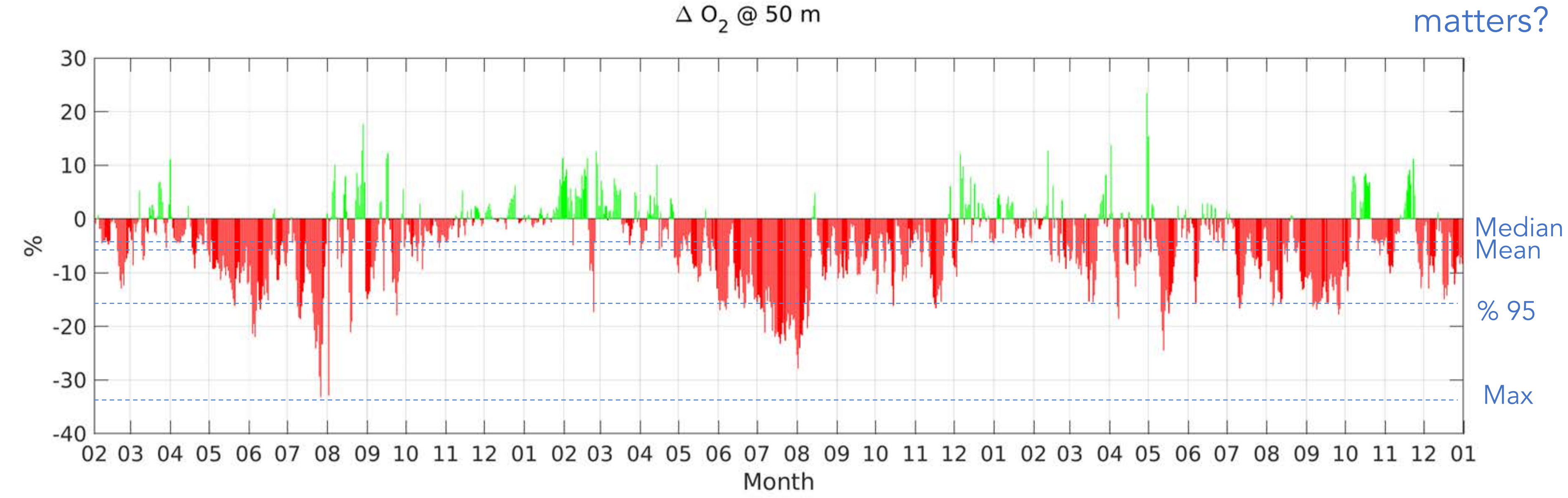
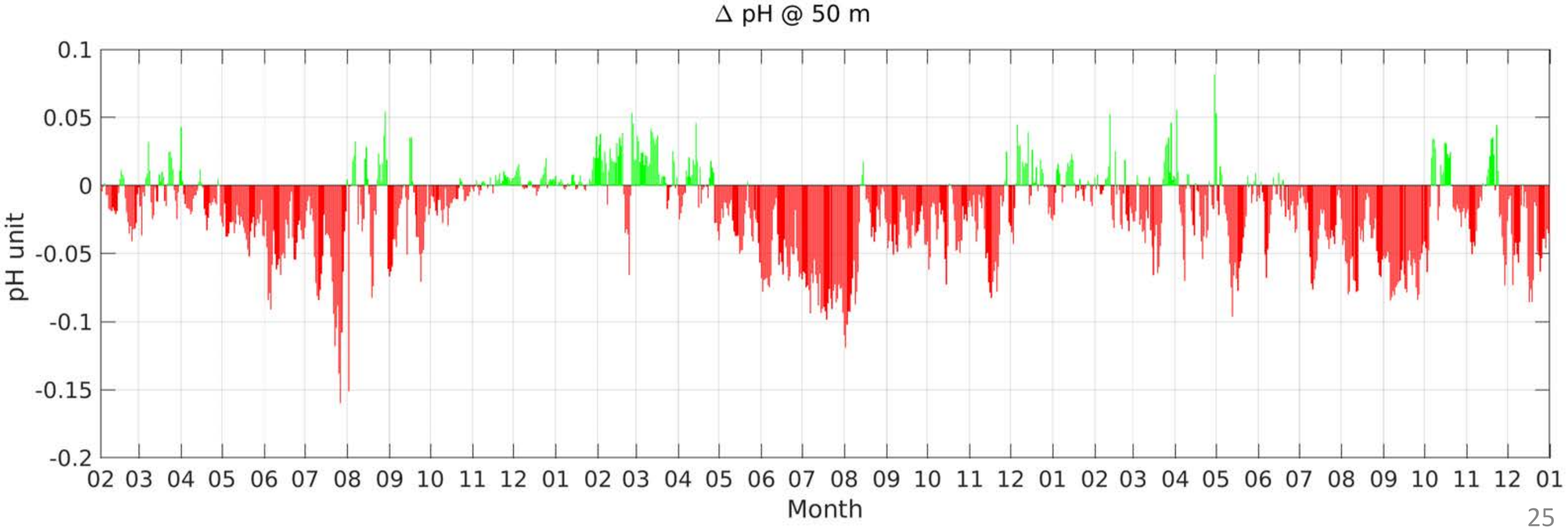
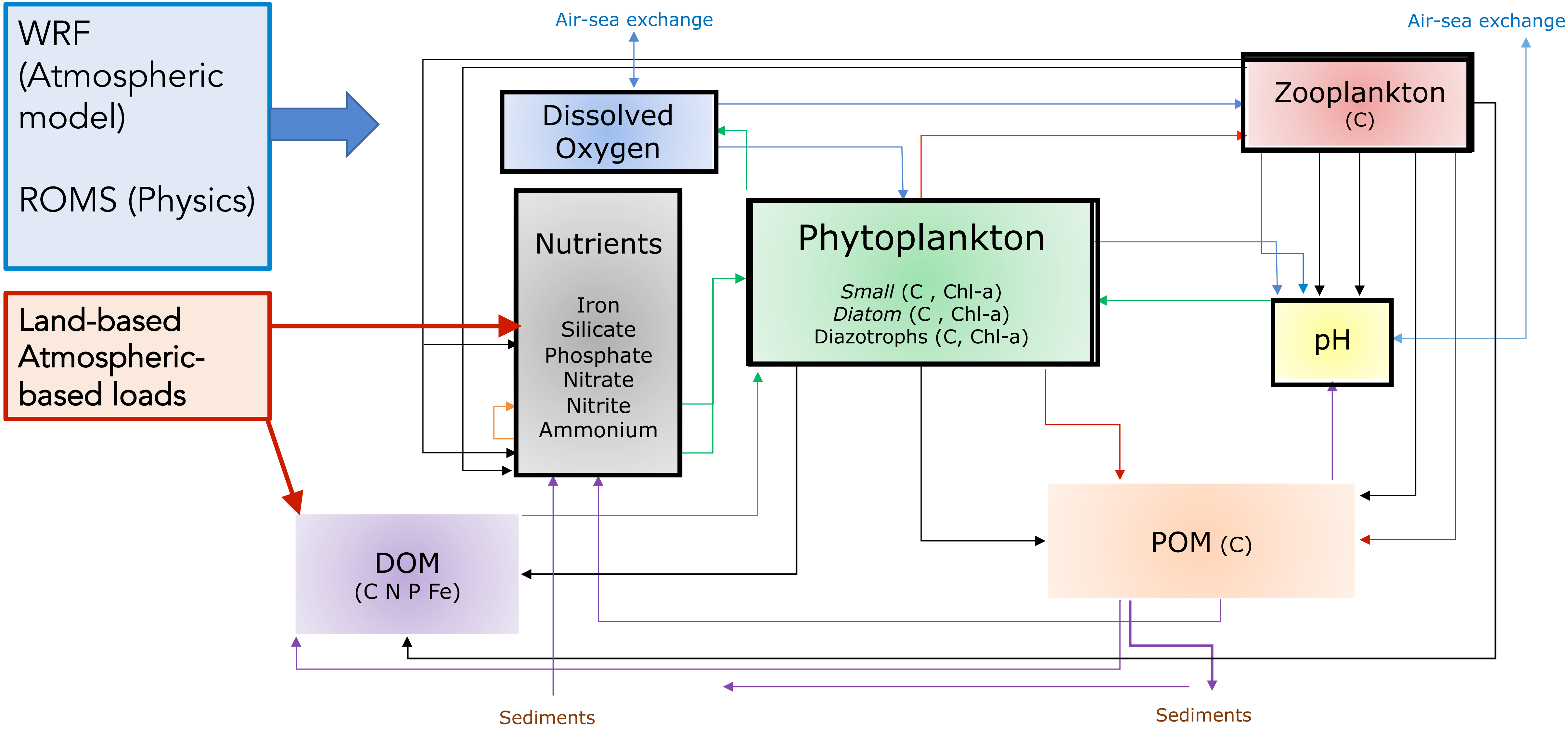
e.g. Santa Monica Bay at 50m depth





BEC simulate acidification



BEC : Comprehensive model of coastal biogeochemistry