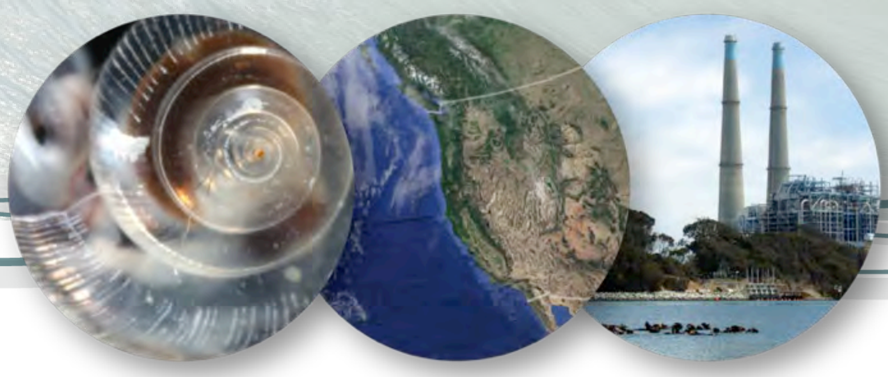
Modeling the Effects of Anthropogenic Nutrients on Acidification and Hypoxia in the Southern California Bight

Commission Update

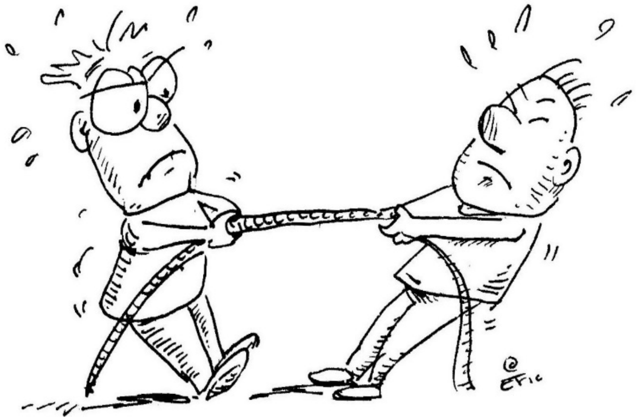


June 21, 2019

Context

- Ocean acidification and hypoxia (OAH) are increasing in California coastal waters
  - Climate change is a big driver
  - Local pollution inputs (nutrients and carbon) may also contribute
- A mechanistic, numerical ocean model is needed that has the ability to disentangle:
  - Natural variability (upwelling)
  - Global climate change
  - [local] anthropogenic nutrient loads

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



Two Opposing Views:

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

Modeling Approach and Overview of Progress

- Build the model

Complete

- Validate the model

Coastwide complete, Significant Progress on SCB anthropogenic validation

- Apply the model
  - Scenarios to assess current day effects of anthropogenic nutrients

First set of scenarios complete

  - Scenarios to assess effect of nutrient management
  - Scenarios to assess future with climate change

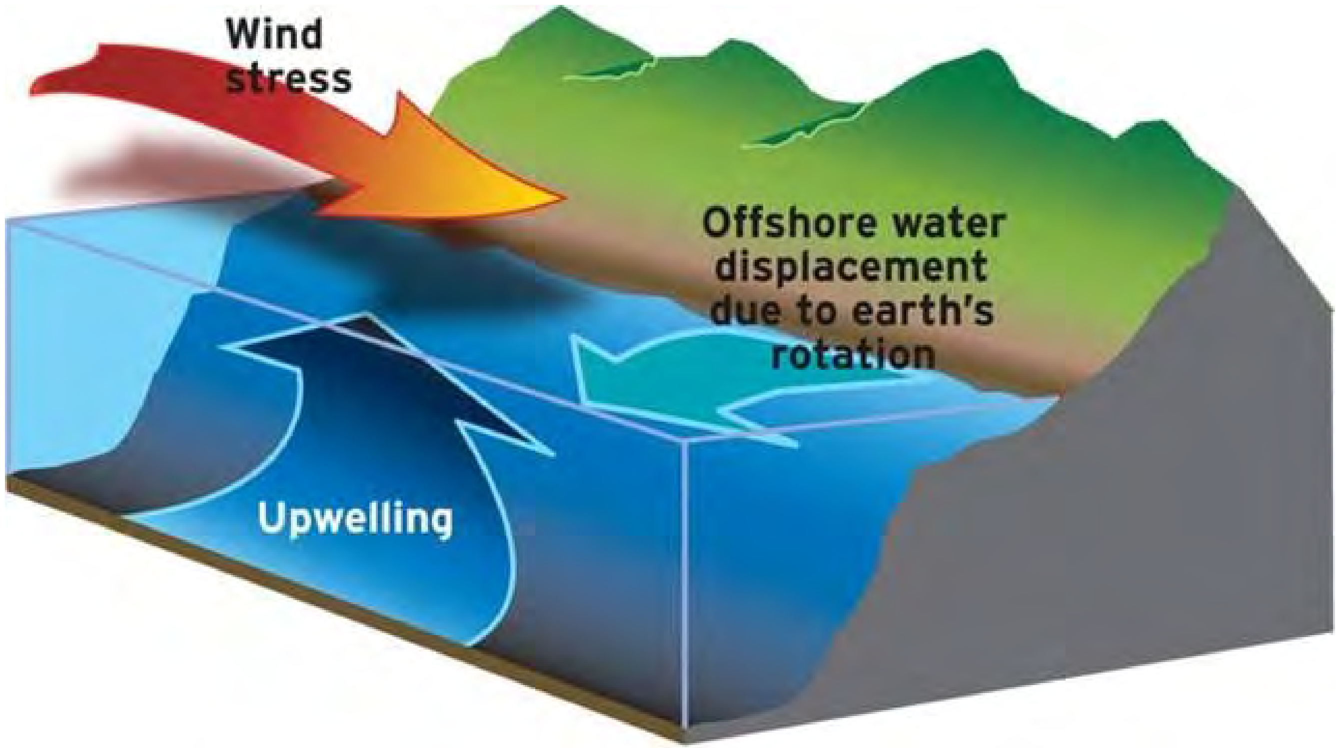
No work undertaken

Model Has Two Components

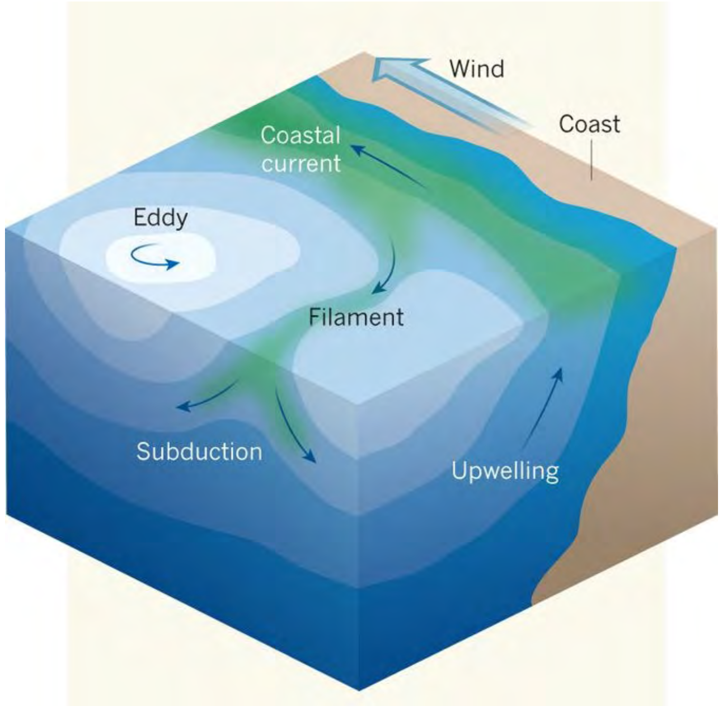
Physical circulation model

Regional Ocean Modeling System (ROMS)

Reproducing upwelling and coastal circulation



"Reproducing Eddies and filaments"



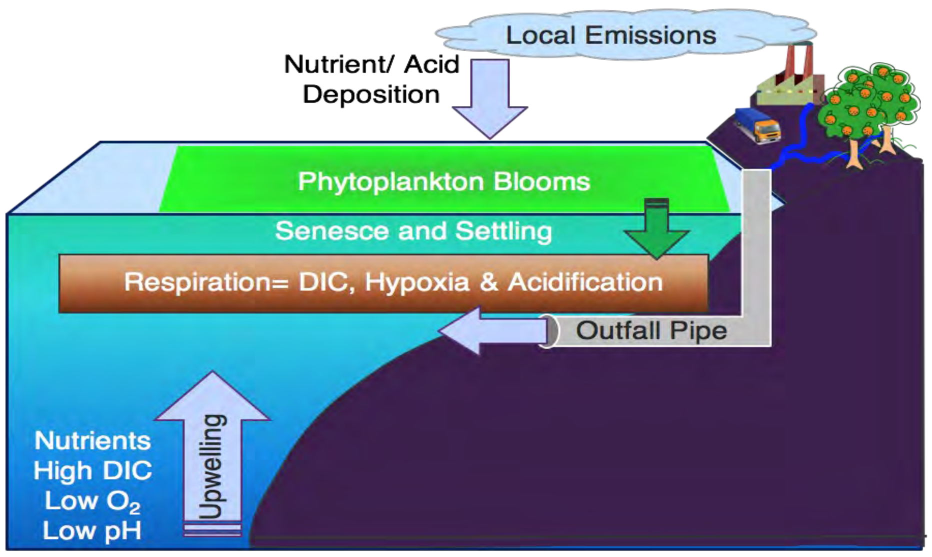
This circulation impacts nutrient transport, O_2 and pH variability in the coastal ocean

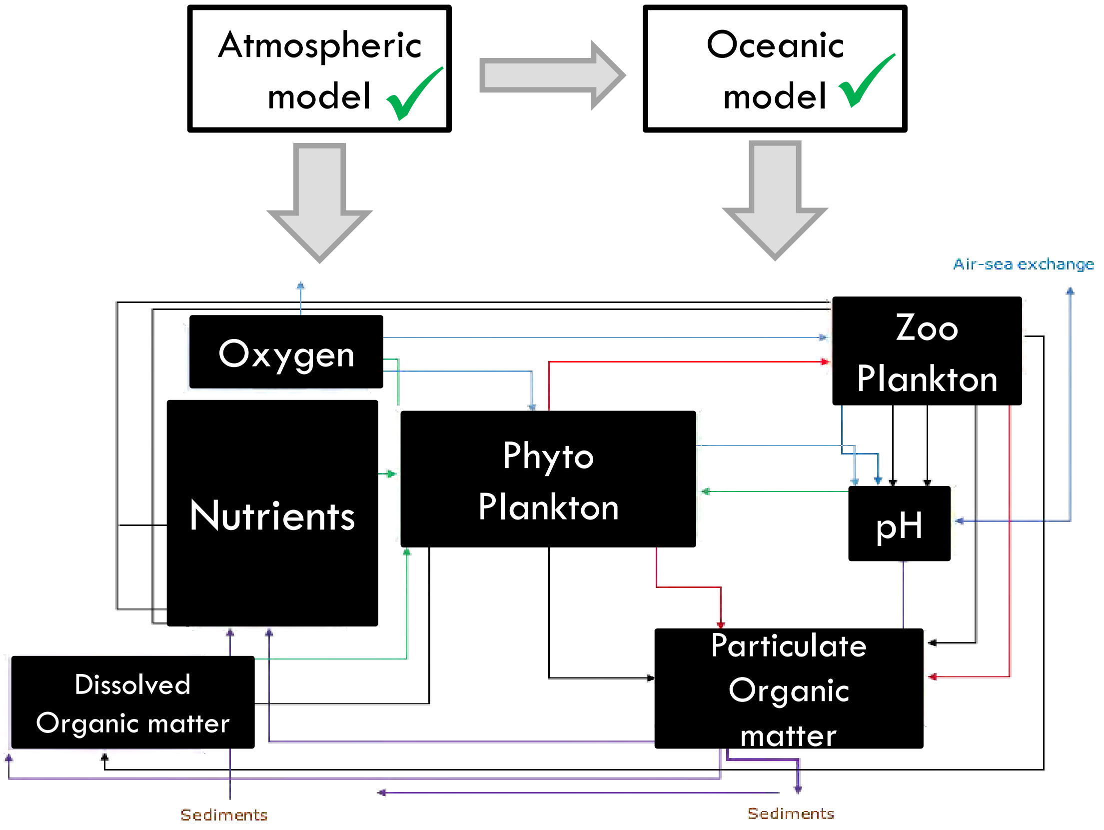
Model Has Two Components

Physical Model is "Coupled" to Biogeochemical & Lower Ecosystem Model (BEC)

Biogeochemical and lower ecosystem (phytoplankton and zooplankton) model track fate of nutrients, organic and inorganic carbon

- And ultimately, their impact on O2 and pH



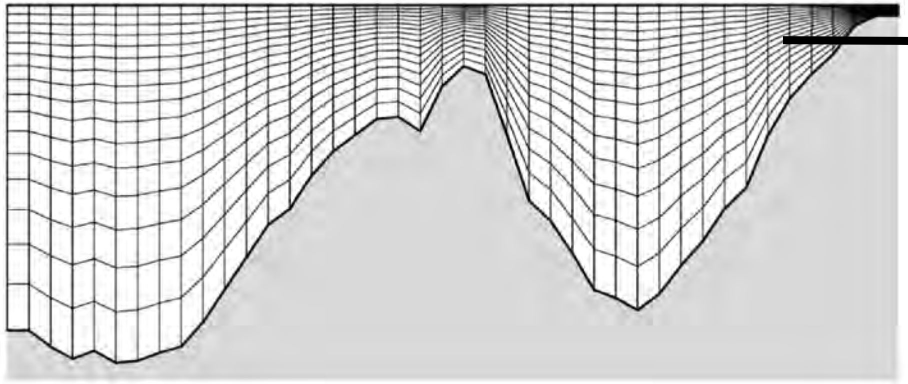


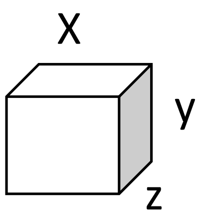
Model is "coupled" with ROMS at same time step, so that we can mechanistically predict impact of physics on biogeochemistry and biology

Model Geographic Scope, Grid, & Resolution

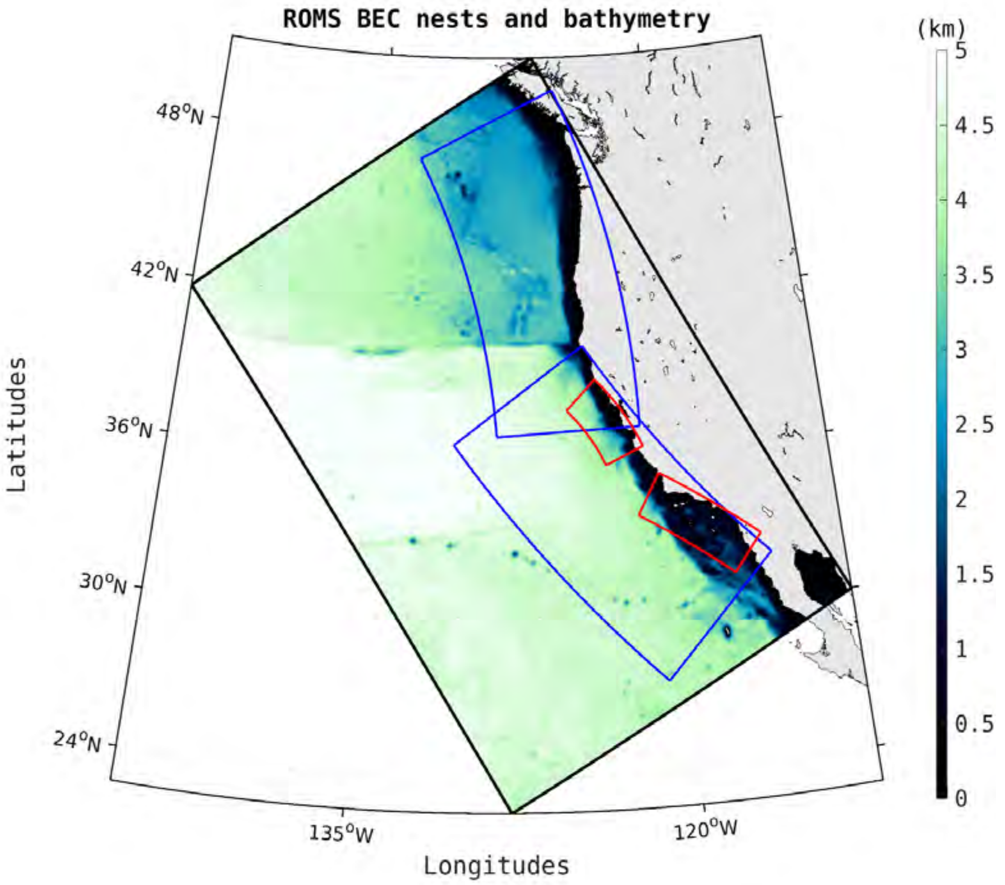
Models represent 3-D space in the ocean. The horizontal length of each cell is the model "resolution"

Full model scope is California Current wide at 4 km resolution, with higher resolution grids "nested" inside (1 km to 300 m)





Grid: 60 variable depth levels and 1410 x 770 horizontal cells



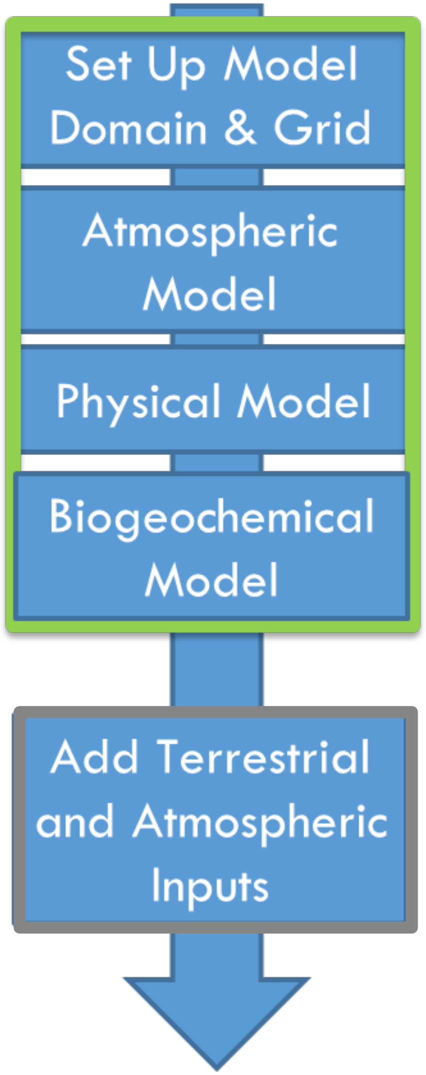
ROMS-BEC mechanistic, 300-m resolution simulations of ocean physics and biogeochemistry is one of the few of its kind in the world

Final Step in Model Development

Input land-based and atmospheric sources of nutrients and carbon

Your comprehensive stormwater and POTW mass emissions data sets were key in simplifying this task for the Southern California Bight

MODEL DEVELOPMENT

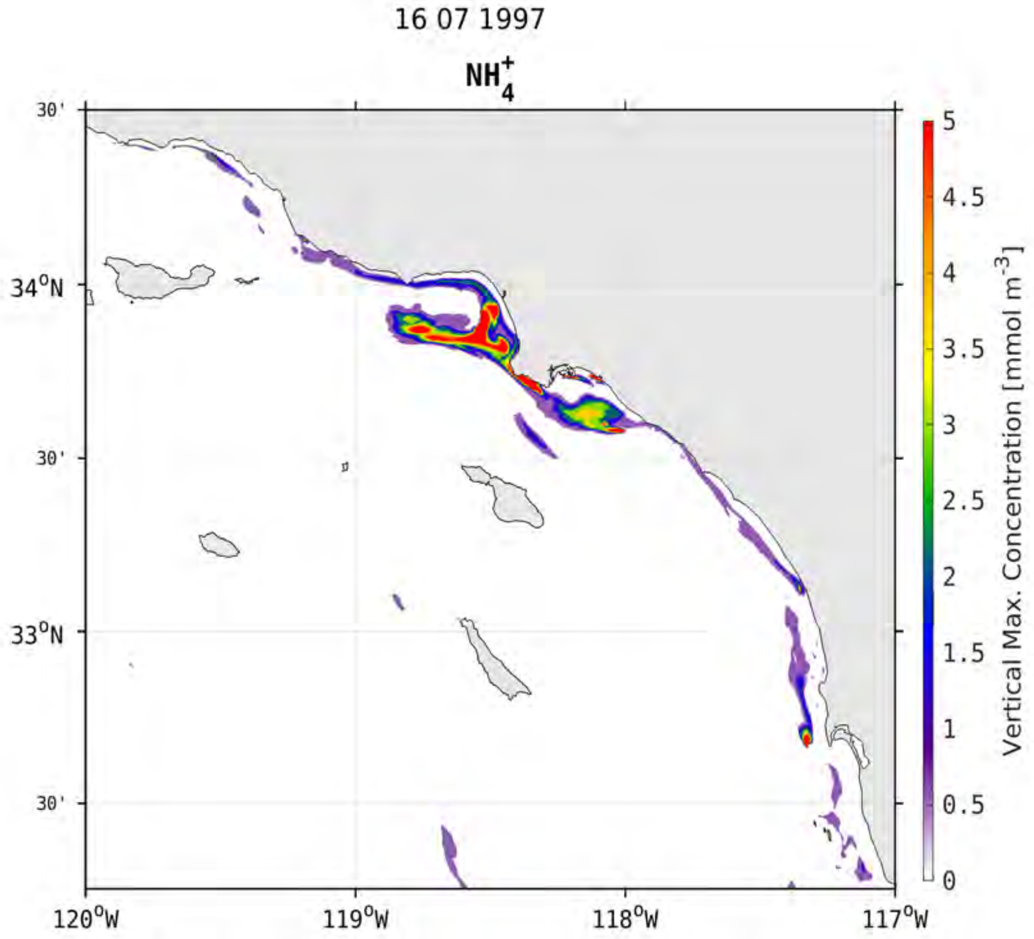


We Ran A 3 Year Simulations With & Without Land-based and Atmospheric Nutrients at 300 m resolution

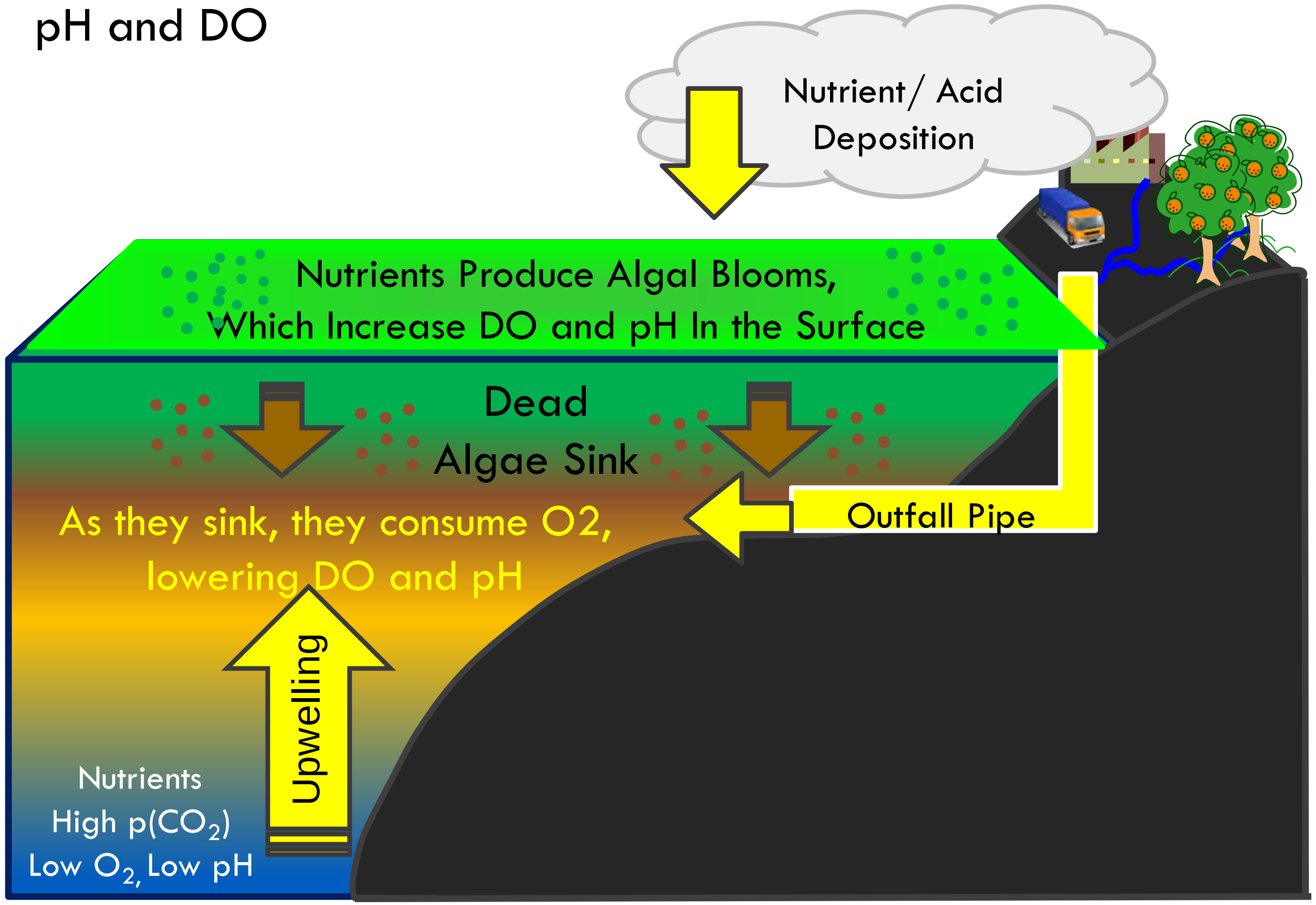
- We validated the model against available observations, focusing on “anthropogenic” gradients”
- We made a preliminary estimate of “effect” of anthropogenic nutrients on chlorophyll-a, DO & pH
- We presented these findings at a recent SAG meeting; we would like to brief you on next steps

What Does the Model Show Happens with Our Anthropogenic Nutrient Inputs?

Anthropogenic nitrogen is broadly distributed over ~20- km band of SCB nearshore



That anthropogenic nitrogen has consequences for subsurface pH and DO



VALIDATION: Model Faithfully Reproduces "Anthropogenic" Gradients in Ocean Observations at Appropriate Spatial and Temporal Scales

(But Among SAG Members, Questions Remain)

Temporal Scales

✓ **Seasonal**

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

Spatial Scales

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

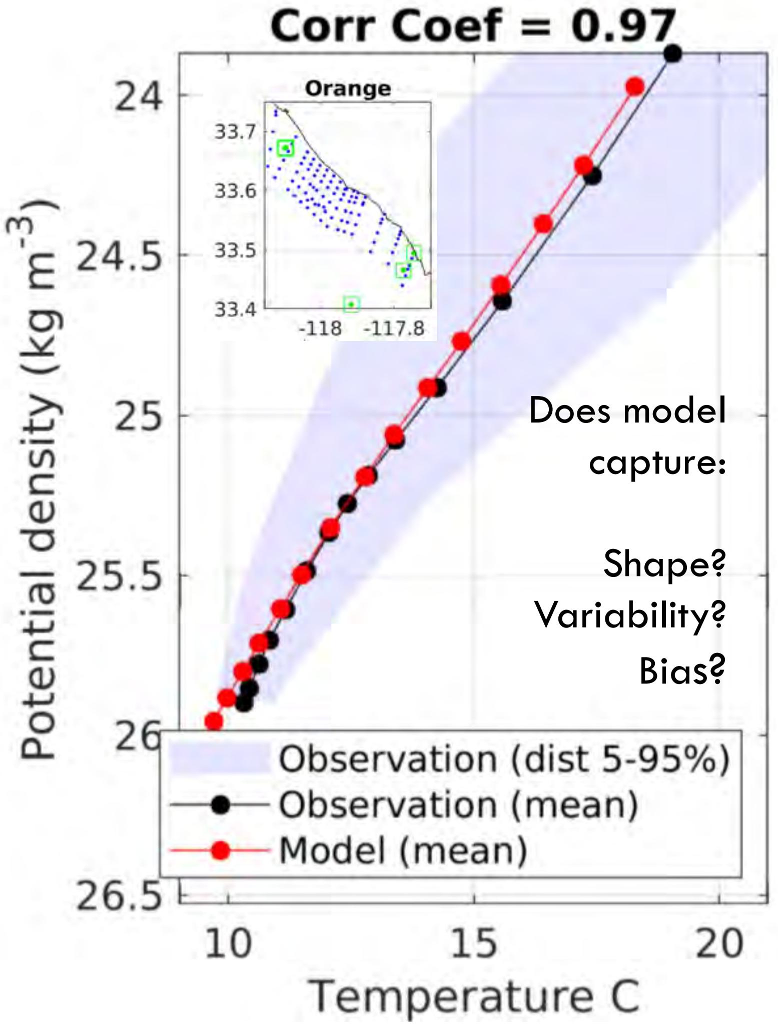
- Appropriate change with depth relative to "mixed layer"

✓ **Alongshore and Cross-shelf**

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

✓ **Plume scale**

- Effects are intensified near outfalls

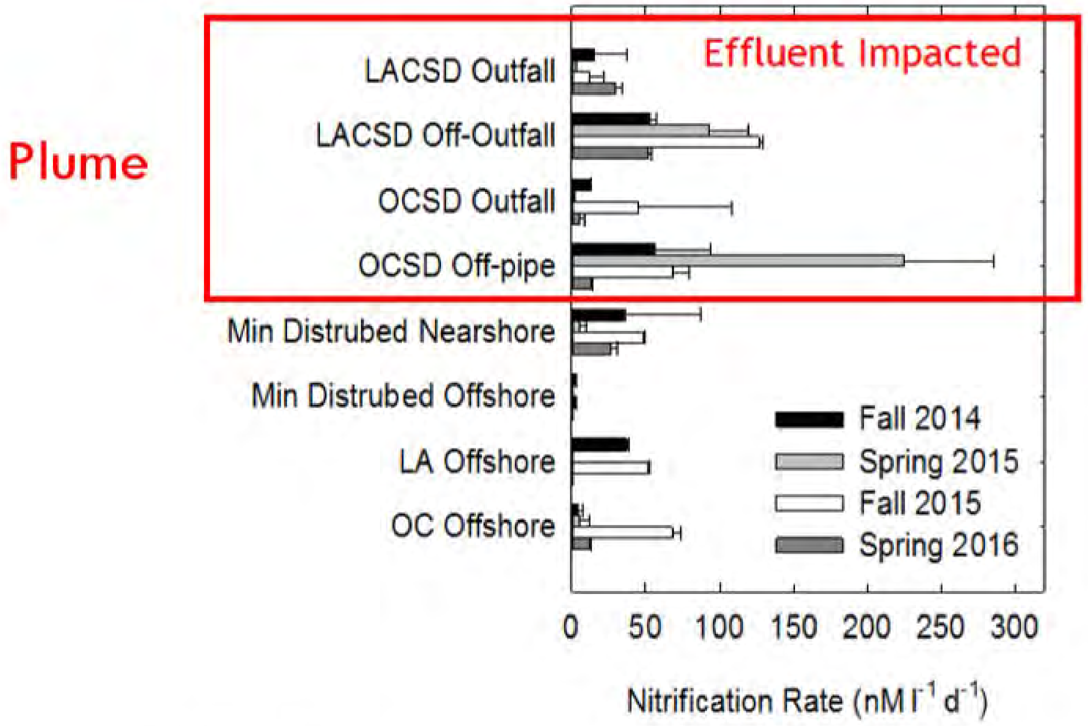


Does model capture:

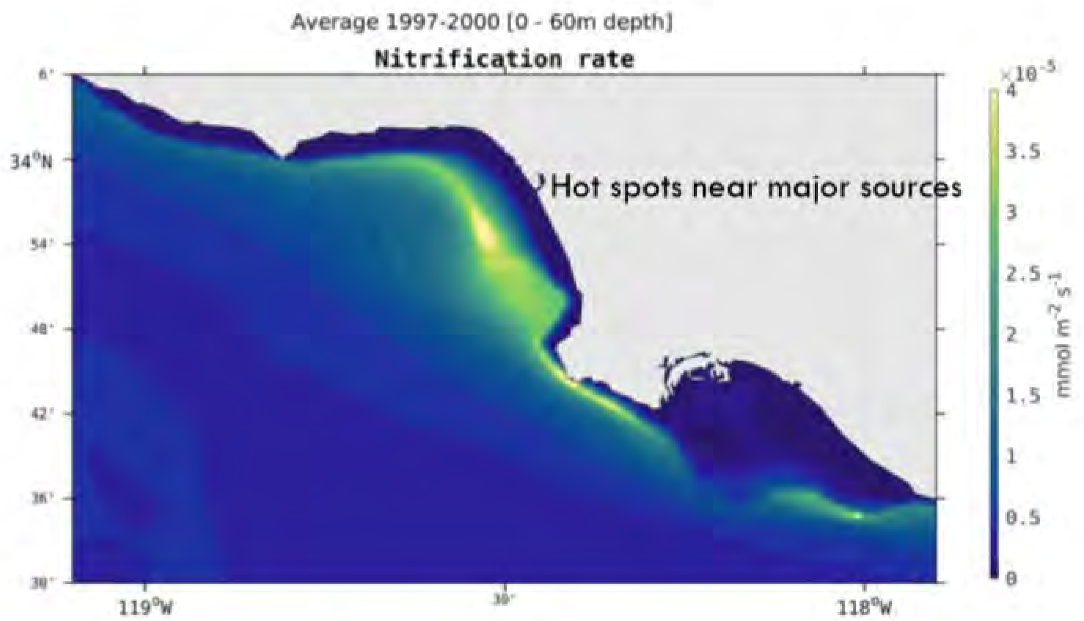
Shape?
Variability?
Bias?

VALIDATION: Comparisons were Made Not only on Ocean Chemical "State", but Also On Biogeochemical "Rates"

Process Studies (Bight '13): We partnered to measure rates of conversion of NH4 → NO3



Nitrification rates within the plume are higher than outside of the plume



Modeled rate show the same pattern

Real Challenge: How Do We Interpret Model Output to Infer an "Adverse Impact"?

- What DO and pH thresholds should we use to interpret model output??

- How do we decide how long (duration) or how many cells (extent) are needed to constitute an "adverse impact"
  - Among 66 million cells, it's guaranteed that at least one will fail any given threshold
  - How many are needed and over what time period to constitute an "adverse impact"?

We Started with Existing Ocean Plan Standards

Ocean Plan Numeric Objectives

DO 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.

These are intended to interpret near-field end-of-pipe effects, not intended to be biologically relevant

Ocean Plan Narrative Objectives

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

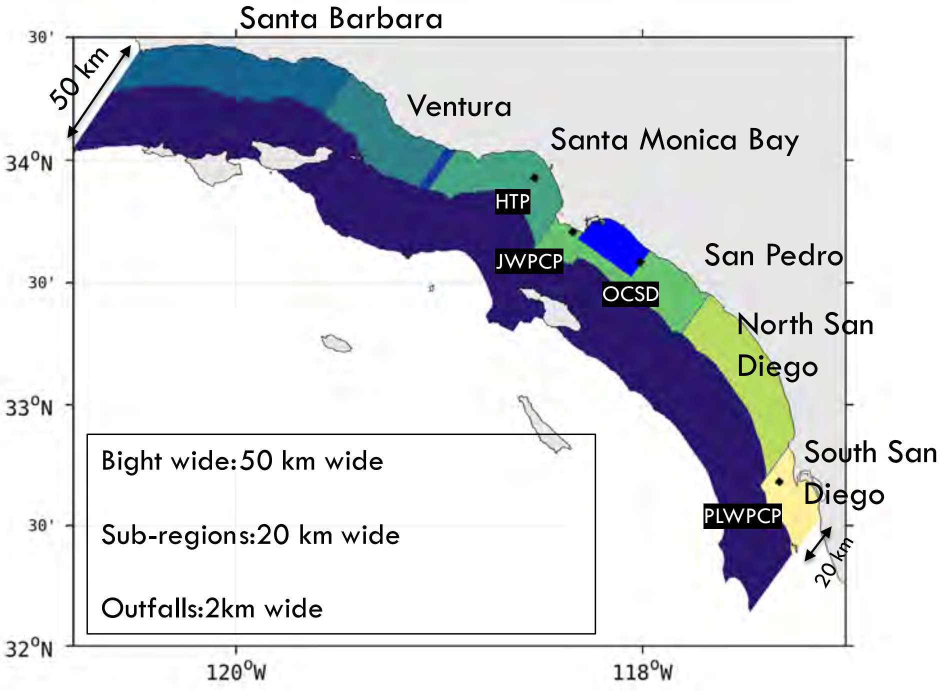
Biological characteristics: Marine communities, including vertebrate, invertebrate, algae and plant species, shall not be degraded.*

Here We Use Recent Science on Biologically Relevant Thresholds for DO and pH to Interpret Narrative

Results Differed for DO and pH Numeric Objectives

pH

- Excursions of pH objective of ± 0.2 pH units never occurred
  - Regardless of spatial scale

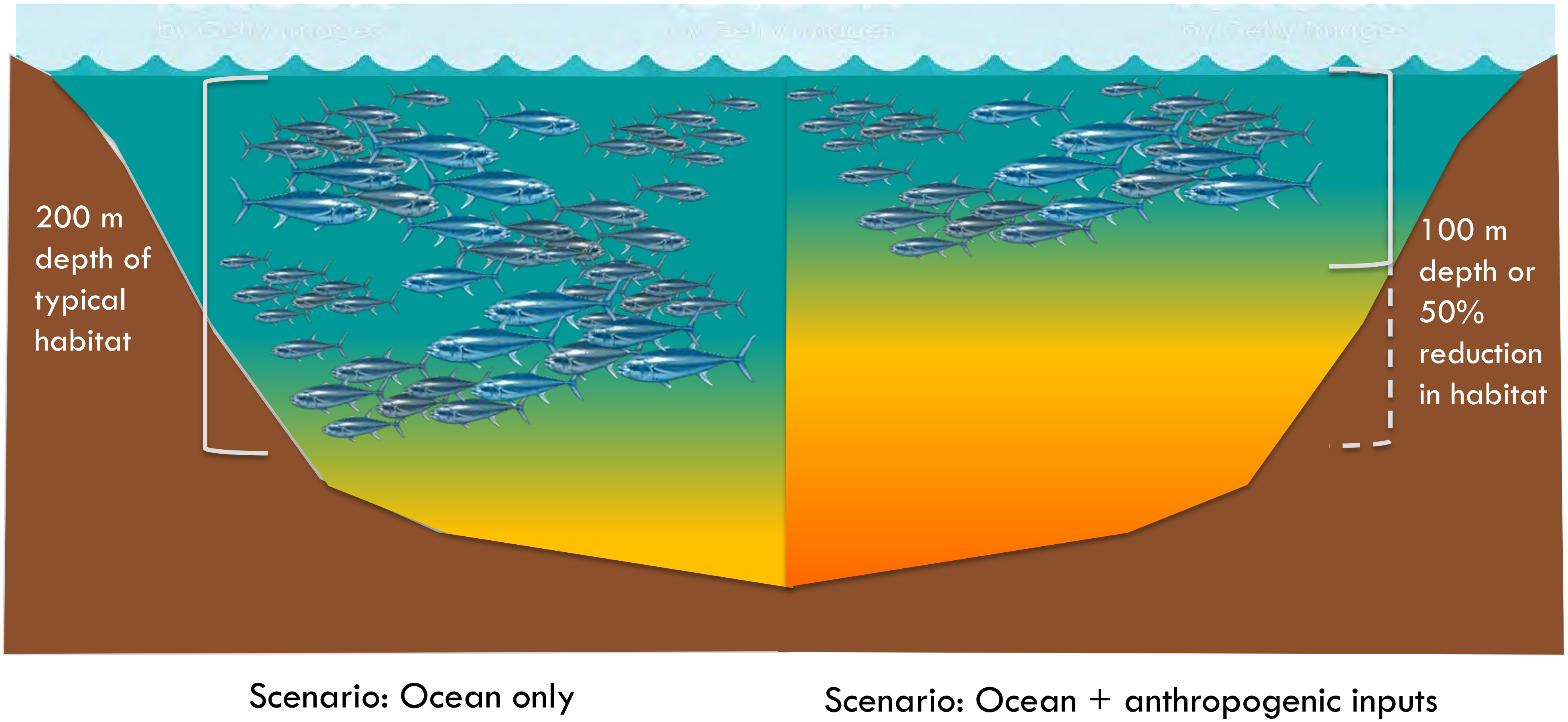


Dissolved Oxygen

- Some excursions of DO of > 10% occurred, with magnitude and frequency of deviation increasing from bightwide to plume scale

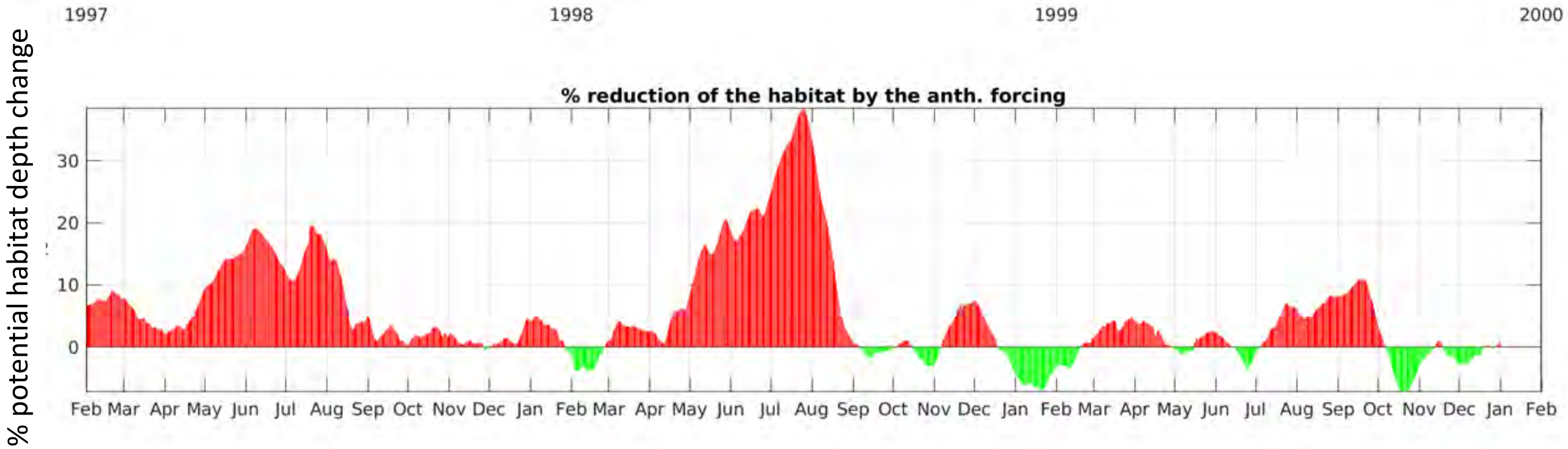
Scale	Max (Negative) DO % Deviation (@ 50-200 m)	Number Days < -%10 over 3 year time series (% of time)
Bightwide	17%	42 (4%)
All Regions	21%	64 (6%)
Santa Barbara	22%	125 (11%)
Ventura	25%	79 (7%)
Santa Monica	24%	65 (6%)
San Pedro	25%	80 (7%)
OC/San Diego North	27%	73 (7%)
San Diego South	25%	97 (9%)
Plume Scale		
Hyperion	31%	240 (22%)
JWCPC	32%	198 (18%)
OCSD	31%	150 (14%)
Point Loma	34%	116 (11%)

When You Apply OAH Biological Thresholds to Scenarios With and Without Anthropogenic Forcing, You Assess Potential Habitat Compression



Excursions of Pteropod OA Thresholds and Anchovy DO Thresholds Occur

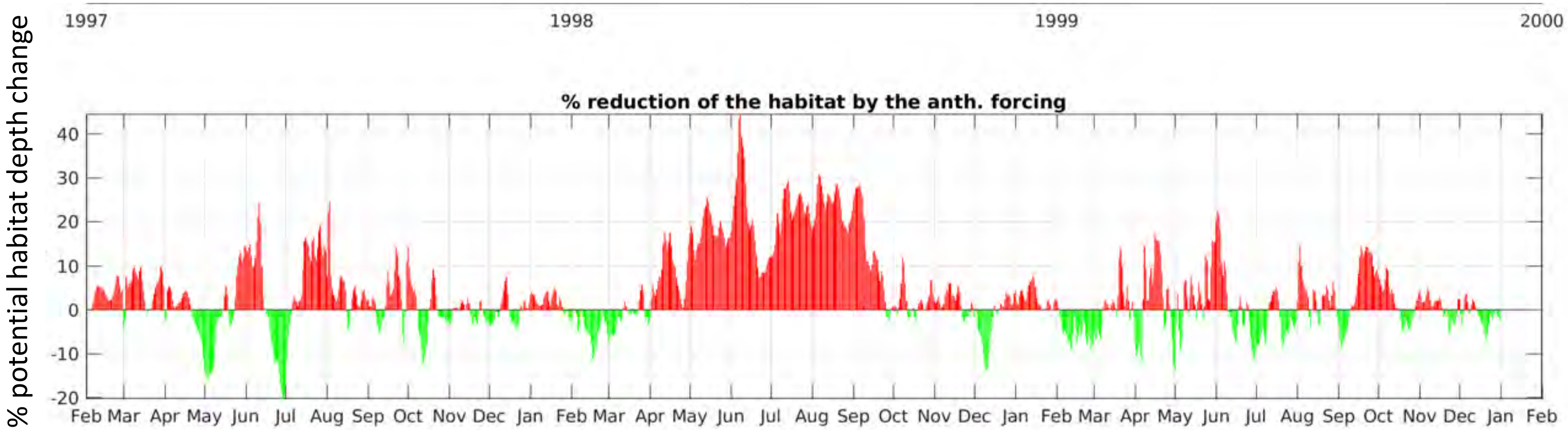
Santa Monica Bay Subregion, Anchovy Aerobic Habitat Change



Northern Anchovy (0-200 m)

Across subregions, max. habitat compression ranges up to ~ 40% for both endpoints, even in regions (e.g. Santa Barbara) that are more distant from sources

Santa Barbara Subregion, Pteropod Reproductive Endpoint

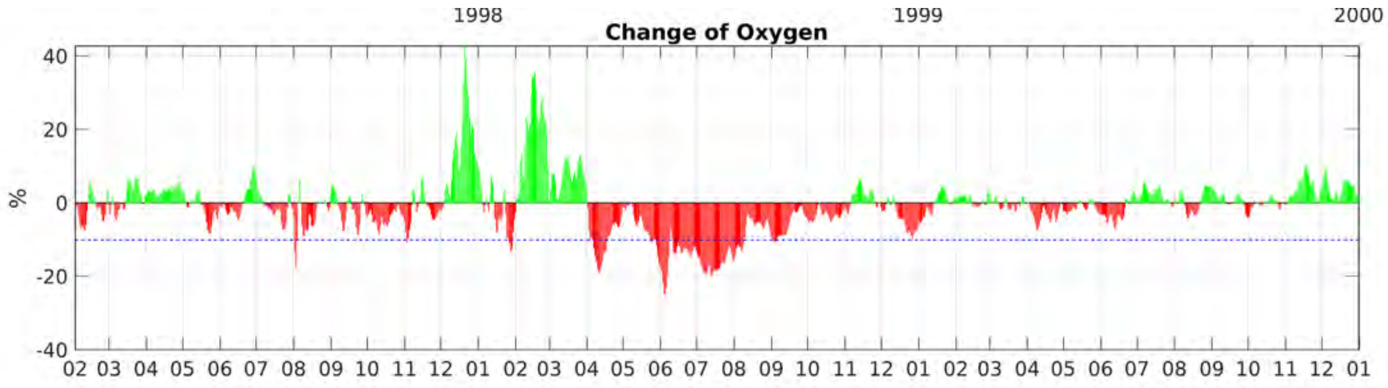


Pteropods (0-200 m)

So, This First Cut Tells Us that Some Excursions of DO WQO and Biological Thresholds Are Apparent, Suggesting Further Work is Needed

But…. We Have Many Decisions to Be Made To Determine Whether Anthropogenic N Is Having a Significant "IMPACT"

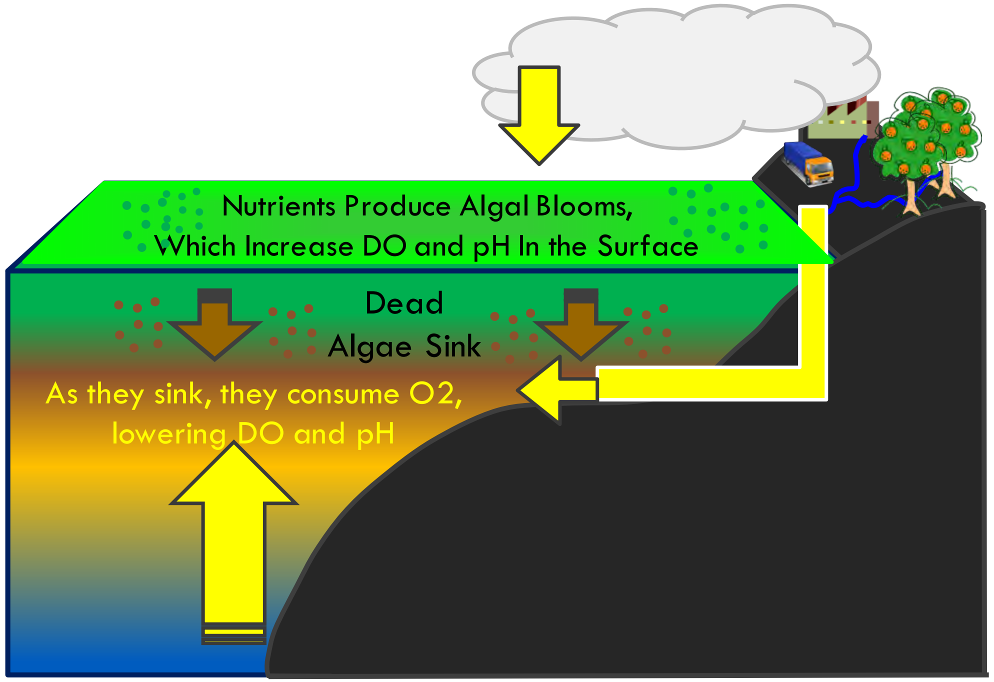
What is the Right Statistic To Calculate Excursions? (I used the Most Stringent Answer in Previous Tables)



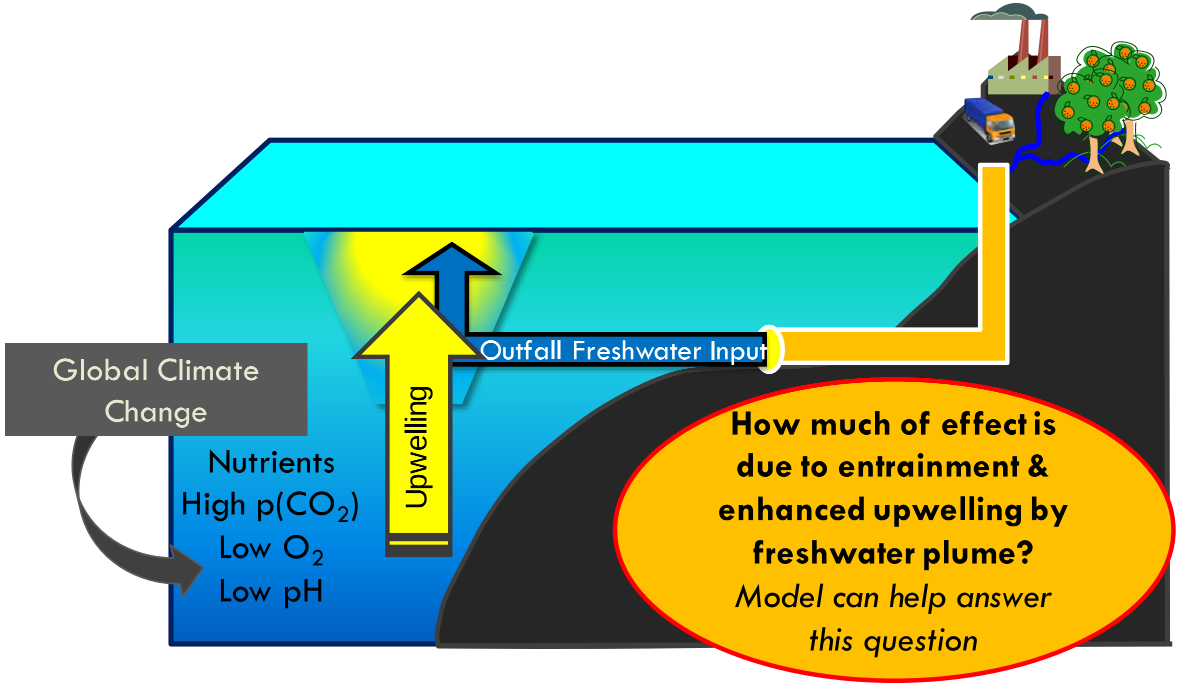
Subregion @ 200 m depth	Median	25th percentile	5th percentile	Minimum (Negative Max)
Bightcoast	0.7%	2.7%	11.0%	15.9%
Santa Barbara	2.7%	5.6%	13.1%	21.6%
Ventura	0.8%	3.9%	11.8%	19.0%
Santa Monica	0.4%	3.4%	11.1%	18.5%
San Pedro	0.4%	3.1%	11.3%	17.6%
SanDiego North	0.2%	3.7%	11.5%	27.0%
SanDiego South	0.8%	4.3%	13.5%	24.8%

More Than Just a Question of Statistics: We Need To Further Investigate What's Driving DO Dynamics in Water Column

We presented this conceptual model as an explanation for what the model simulations are showing



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



Devil in the Details: Lots of Decisions to be Made that Can Affect Outcome

__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 or cumulative impact?
- Effect of freshwater only versus nutrients and organic matter?

__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?
  - Extent and severity of effect requires additional interpretation by biologists
  - Best metric of change? Absolute depth change, percent change?

From SAG Meeting: Next Steps

- Complete validation to the SAG' s satisfaction
- Run additional model scenarios that address the most prominent management questions identified by the SAG
- Develop an approach to interpret "impacts" for the existing (and new) model runs

Formed Two Subcommittees

- Validation and new model scenarios- George Robertson OCSD

- Interpretation Approach – Katherine Walsh, State Water Board

Subcommittees are forming over the summer; we can update you on their plans as requested

Questions?