

# OCEAN NUMERICAL MODELING IN SUPPORT OF COASTAL WATER QUALITY MANAGEMENT: A PROGRESS REPORT

Martha Sutula, PhD

Principal Scientist, Biogeochemistry Department  
Southern California Coastal Water Research Project Authority

On Behalf of Colleagues From



# WHAT IS THE SO. CALIFORNIA COASTAL WATER RESEARCH PROJECT AUTHORITY (SCCWRP)?

- **Environmental research institute focused on science to improve management of aquatic ecosystems**
  - Key part of our mission is translating this science to the management community of Southern California and beyond
- **Commission comprised of 14 member agencies charged with protection of the Bight aquatic habitats**
  - Four major sanitary agencies and four county stormwater agencies that discharge to the coastal watersheds and the Southern California Bight
  - Water quality regulators (State and Regional Boards, USEPA) and coastal policymakers (California Ocean Protection Council)
- **We meet quarterly with Commission technical staff and executive managers to brief them on the readiness of science to support decisions**

# CONTEXT FOR TODAY'S DISCUSSION

- **SCCWRP is co-lead of team using models to investigate how human nutrient sources are impacting coastal water quality, with two geographic foci**
  - Southern California Bight
  - San Francisco and Monterey Coast (SFMC)
- **The work in the Bight is transitioning from model development to management application**
  - While the SFMC modeling is still in the early phase
- **BACWA requested a status briefing on this work**
  - Ideal timing, since we are at a juncture where stakeholder engagement would be helpful

# BACKGROUND

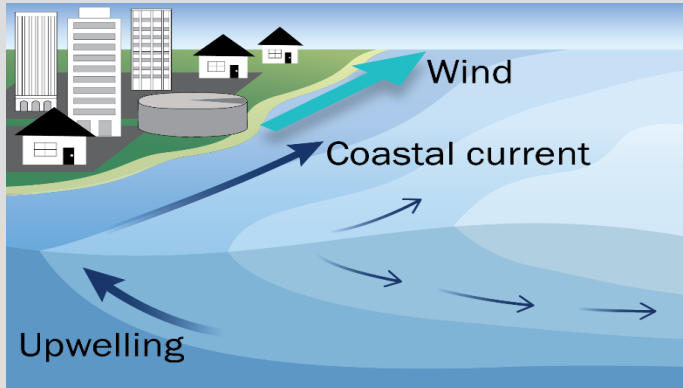
- **15 years ago, Stanford's Center for Ocean Solutions suggested nutrient limits on wastewater treatment plants to reduce coastal acidification**
- **12 years ago, the West Coast Ocean Acidification Task Force made a similar suggestion**
  - However, their recommendation was more cautious
  - They suggested using a model to evaluate magnitude of change from such expensive actions
- **SCCWRP's Commission encouraged us to undertake that modeling effort**
  - We partnered with UCLA and Princeton to do so
  - Collaboration is grown to 25 + scientists across 5 institutions, including SFEI

# COASTAL NUMERICAL MODEL AND BIOLOGICAL INTERPRETATION TOOLS

## ROMS

### Regional Ocean Modeling System

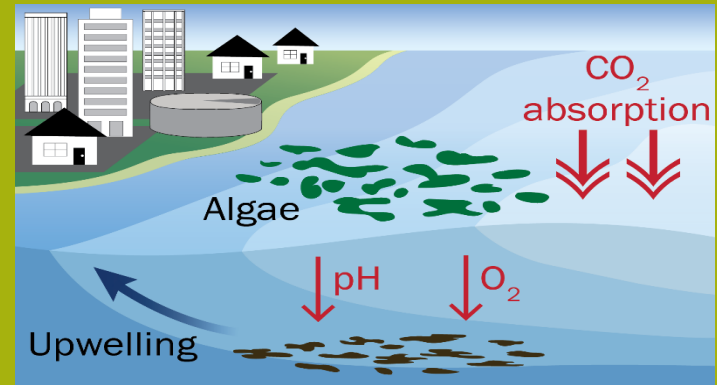
A physical circulation model that predicts how ocean water circulates



## BEC

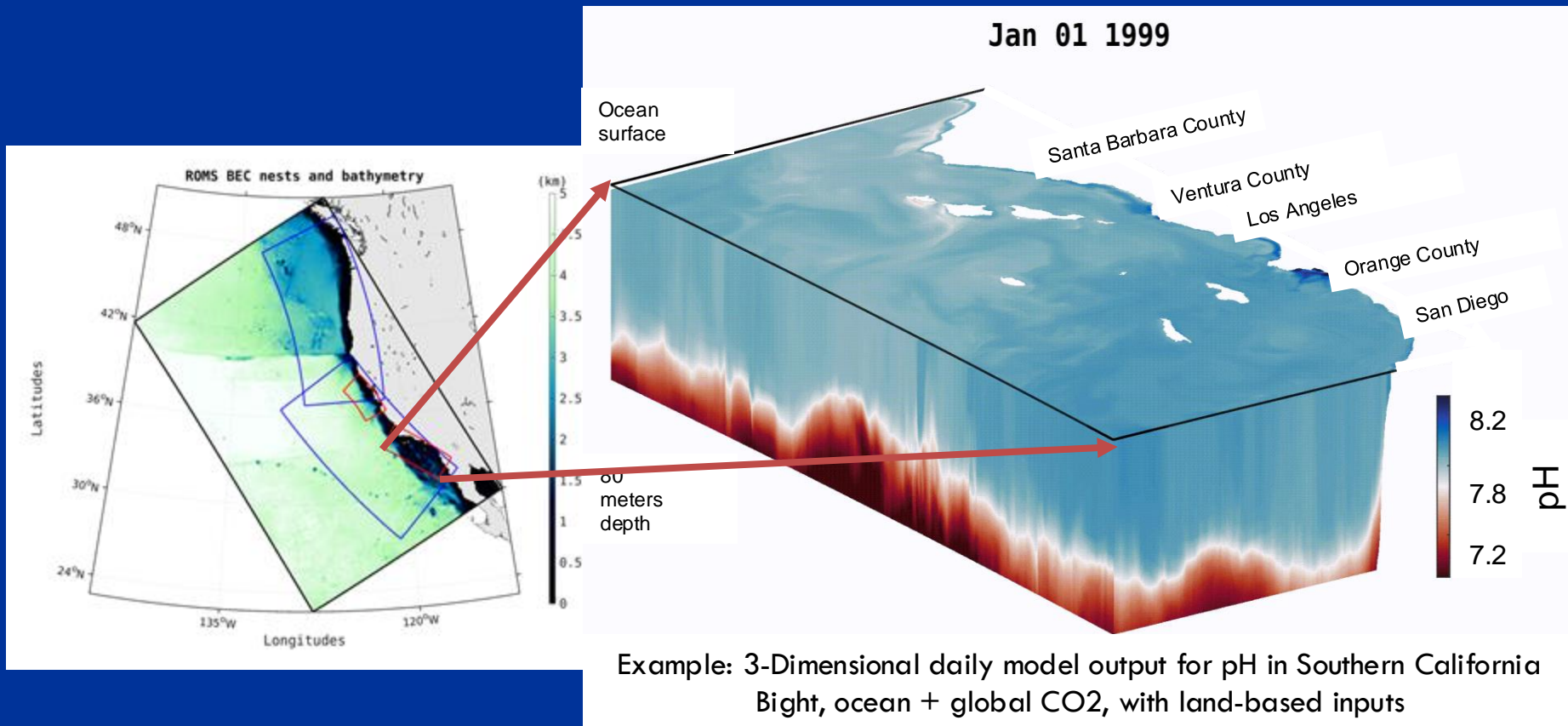
### Biogeochemical Elemental Cycling Model

Predicts how human & ocean nutrient fuel plankton blooms that consume oxygen and lower pH



**TOOLS TO TRANSLATE CHANGES IN SEAWATER CHEMISTRY ON BIOLOGICAL IMPACTS**

# ROMS-BEC Is Implemented Coastwide, With Finer Resolution Nests in Regions with Specific Water Quality Applications



# WE WORKED TO DEVELOP A SUITE OF THRESHOLDS TO TRANSLATE CHEMISTRY TO BIOLOGICAL EFFECTS

Led working groups of experts to get consensus on OA thresholds for three types of shelled organisms



Acidification

Developed and validated indices that capture how oxygen changes impact the abundance of fish



Hypoxia

[Emerging science] Extending modeling to predictions of toxic harmful algal blooms (domoic acid producing Pseudo-nitzschia)



HABs

# PRESENT DAY

- **We spent ten years building and validating the model and biological interpretation tools**
  - Published more than 50 journal manuscripts describing this work
- **Four years ago, we started transitioning from development to application, focusing on effects of human nutrients in the Bight**
  - We mostly ran bookend scenarios
  - Those bookends indicated nutrient inputs have a non-trivial effect on algal production, local acidification and hypoxia, with biological consequences
- **Some community members were concerned whether the model was mature enough for use as a tool to guide nutrient management decisions**
  - Independent expert panel formed to review the model issued their report last fall
  - “Model was fundamentally sound” and provided ways to improve stakeholder confidence
  - Steering Committee is working together to implement those recommendations for the Bight



# SFMC MODELING HAS BEEN PROGRESSING IN PARALLEL, LED BY UCLA, IN COLLABORATION WITH SFEI AND UCSC

## First phase focused on three foundational pieces:

- **Model development**
  - Data gathering for inputs, calibration and validation
  - Model set up and verification
- **Preliminary validation studies**
  - Physics
  - Biogeochemical gradients
- **First order attribution of the effects of three pathways for nutrient inputs**
  - San Francisco Bay exchanges
  - Coastal outfalls
  - Central coast rivers

# PHASE I STUDY OUTCOMES AND PRELIMINARY FINDINGS

- **Successfully implemented ROMS-BEC in the SFMC**
  - Overcoming challenges: representing SFB exchanges at the Golden Gate
- **Model skill assessment shows model reproduces first-order, large-scale patterns in physics, nutrients, chlorophyll, productivity, oxygen**
  - NMS funded post-doc led the physical validation
- **50% of inputs to SFMC dominated by SF Bay exchanges**
  - Pathway attributions shows substantial effect of SF Bay outflows on primary productivity
  - Notable effects on pH and O<sub>2</sub>, but no analysis yet of impacts to habitat
- **Monterey coastal agriculture-dominated rivers are 2nd major source**
  - Effects in Monterey Bay notable
  - But representation of coastal rivers need refinement

# SFMC PHASE II WORK IS JUST STARTING

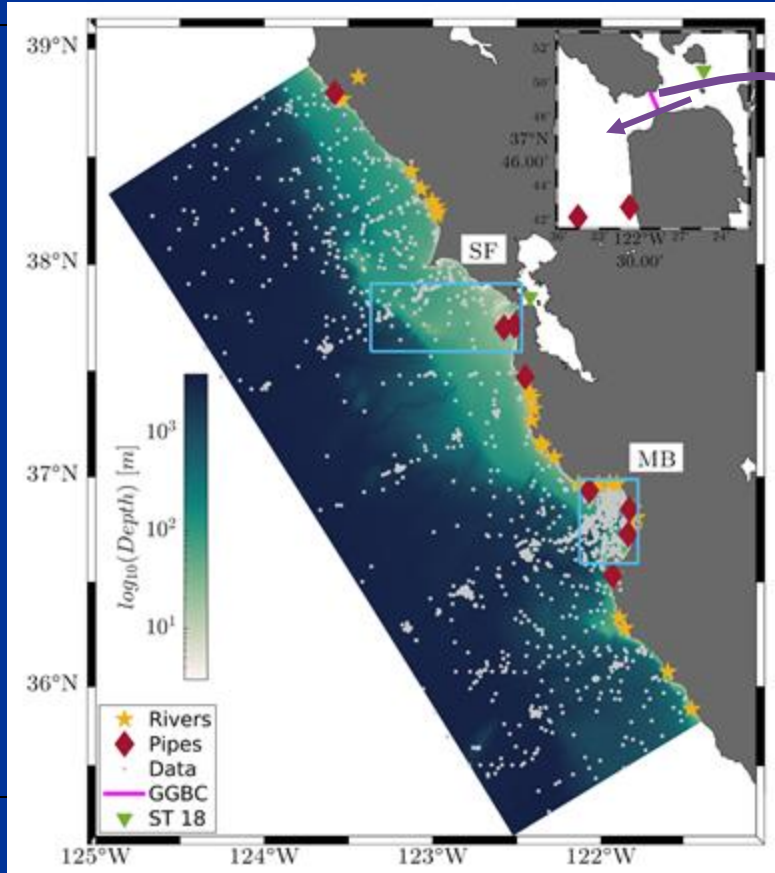
## Five Tasks, Over 3 Years

1. **Draft science workplan**
2. **Update terrestrial inputs**
  - Improve representation of Central Coast rivers with USGS dynamic models
  - SFEI SF Bay model as the basis for GG outflows
3. **Conduct outreach with stakeholders from SFB and Monterey Coast**
  - Get their feedback on workplan and inputs
4. **Conduct an extended simulation**
  - Update skill assessment
5. **Interpret biological effects**
  - Habitat compression for OAH
  - Window of opportunity for Pseudo-nitzschia HABs

**QUESTIONS?**

**MARTHA SUTULA**  
**MARTHAS@SCCWRP.ORG**

# MODEL SET UP AND FORCING



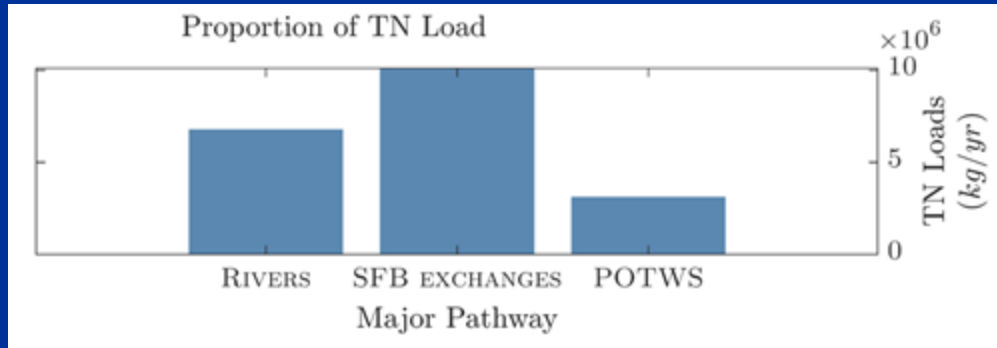
Exchange at the Golden Gate driven by biogeochemical model inside SF (nat + ant).



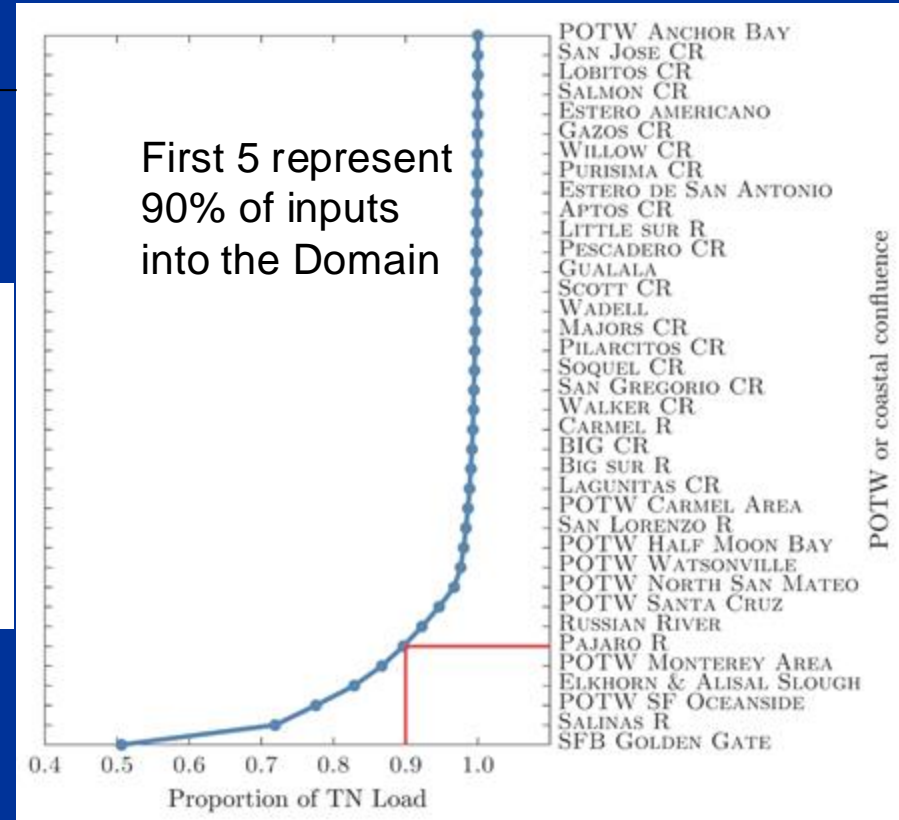
Simulations run for ocean conditions during 2011-2013

# COMPILED DATA ON COASTAL OUTFALLS AND RIVERS

- 8 coastal POTW ocean outfalls
- 28 coastal rivers



- SFB Exchange ~ coast rivers + ocean outfalls.
- Coastal rivers ~ 3x coastal POTWs.



*Sutula et al. in prep*

# PRELIMINARY VALIDATION FINDINGS

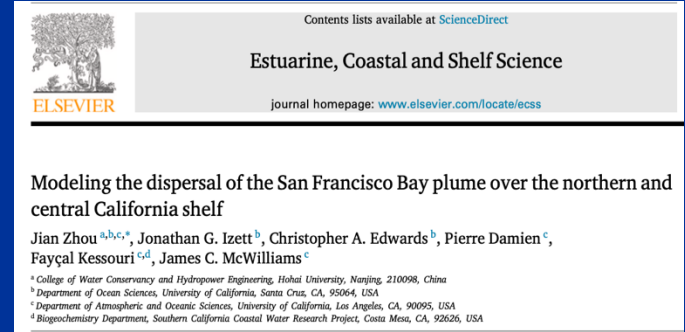
## MODEL REPRODUCES FIRST-ORDER, LARGE-SCALE PATTERNS

### Physical State (Zhou et al., 2023)

- Temperature, salinity, spatial & seasonal patterns
- Currents and dispersal of San Francisco Bay plume

### Chemistry

- **Inorganic nitrogen, phosphorus patterns**
  - Vertical profiles, gradients, seasonal cycle
- **Phytoplankton / Lower trophic level:**
  - Satellite and field measured Chlorophyll and primary production
- **Oxygen and pH:**
  - spatial gradients, seasonality, extremes



*Dissertation complete*  
*Manuscript in prep,*  
*Sandoval-Belmar et al.*

# PRELIMINARY FINDINGS: PATHWAY ATTRIBUTION

*Manuscript in prep, Sandoval-Belmar et al.*

## **Substantial effect of San Francisco Bay exchanges on primary productivity**

- Potential to widen the window of opportunity for *Pseudo-nitzschia*
- Effects on oxygen and pH notable, but we haven't yet translated them to estimates of habitat compression

## **Monterey coastal effects are also evident, but model refinements are needed**

- Coastal rivers need refinement
- And we also need a longer set of simulations because of variability in land-based inputs



# THREE TYPES OF PANEL FEEDBACK

- **Soundness of the model and model output interpretation**
- **Activities to further quantify model uncertainty**
- **Steps we can take to enhance community acceptance**

# SUGGESTED IMPROVEMENTS

- **Place model findings into context of California Current-scale patterns**
  - Example: Identify places of particular ecological concern (either to anchovy or the food web they support) and present water-quality impacts on those places specifically, not only on the Southern California Bight as a whole
- **They offered a note of caution about not extending the model beyond the scales for which we have validated it**
  - “As is the case with all modeling systems, ROMS-BEC has limitations and, specifically, does not capture all physical and biogeochemical processes relevant to the discharge of treated wastewater. For example, the model needs more evaluation with observations in the near field of outfalls and nearshore coastal region to ensure an adequate depiction of highly variable shallow water processes”
- **They provided no recommendations for necessary improvements before using the model to address management questions**
  - Instead, the report focuses on things we can do to better understand model uncertainty

# FURTHER QUANTIFY MODEL UNCERTAINTY

- **Conduct comparisons with additional observational variables**
  - Subsurface nutrient concentrations
  - Sediment trap data
  - Light (Photosynthetically active radiation)
  - Primary productivity
  - Apparent oxygen utilization
  - Observations in the near field of outfalls and nearshore coastal region
- **Conduct additional sensitivity analyses**
  - Zooplankton grazing
  - Relative preference of phytoplankton groups for nitrate and ammonium
  - Particle sinking and remineralization rates
  - Natural nutrient inputs
  - Light attenuation
  - Nitrate uptake half-saturation constant

# ENHANCE COMMUNITY ACCEPTANCE

- **Automate production of graphical comparisons and summary statistics**
- **Provide close-to-full model output, rather than summarized data**
  - Daily averages of key variables at key depths, across the full model domain
- **Comparisons with observations that follow norms in the engineering community as opposed to the conventions of scientific publishing**
- **Create a system for associating output datasets, model-observation comparisons, and scientific publications with versions of the model's source code**