# Overview of Modeling Science Presentations

**December 12, 2023 webinar:** Overview of work and roadmap to published works

**January 9, 2024 webinar:** ROMS-BEC Model development, validation and biological interpretation tools

**January 17-18, 2024:** Model configuration, model application and validation to investigate the effects of land-based inputs in the Southern California Bight

# THREE TALKS DESCRIBE WORK TO INVESTIGATE THE EFFECTS OF ANTHROPOGENIC NUTRIENTS IN THE SOUTHERN CALIFORNIA BIGHT

**Compilation/Configuration of SCB Model** -------- Faycal Kessouri, Ph.D & Martha Sutula, Ph.D.

**Model Applications** ---------------------------------- Christina Frieder, Ph.D.

- Investigate effect of anthropogenic nutrients on seawater chemistry and biological effects
- Conduct management scenarios

**Model Validation** ------------------------------------- Faycal Kessouri, Ph.D.

# Introducing January 17-18, 2024 Workshop Speakers

Dr. Martha Sutula,

Head, Dept. of Biogeochemistry
Southern California Coastal Water
Research Project Authority

Dr. Faycal Kessouri, Senior Scientist,

Dept. of Biogeochemistry
Southern California Coastal Water
Research Project Authority

Dr. Christina Frieder, Senior Scientist,

Dept. of Biogeochemistry
Southern California Coastal Water
Research Project Authority

# Introducing Rest of Team (Introduced Via Webinar)

Dr. Jim McWilliams, Professor,

Dept. of Atmospheric & Oceanic Sciences
University of California, Los Angeles

Dr. Curtis Deutsch, Professor,

Dept. of Geosciences & High Meadows Environmental Institute
Princeton University

# Introducing Rest of Team (Not Yet Introduced)

Dr. Daniele Bianchi, Professor,

Dept. of Atmospheric & Oceanic Sciences
University of California, Los Angeles

Minna Ho, Scientist

Dept. of Biogeochemistry
Southern California Coastal Water Research Project Authority

# Inputs To ROMS-BEC for Anthropogenic Nutrient Applications

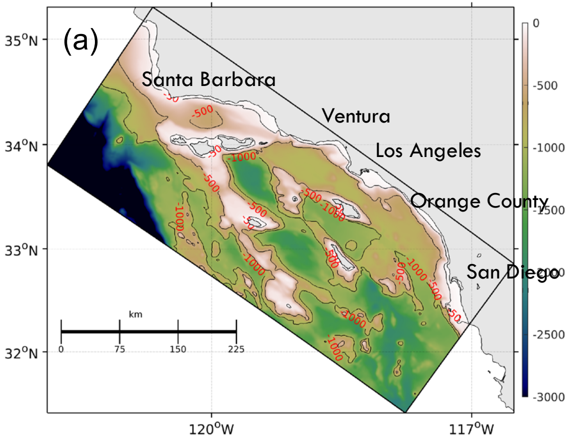
Martha Sutula, Ph.D.
Biogeochemistry Department
Southern California Coastal Water Research Project Authority

On Behalf of Colleagues From

# SEVERAL STEPS WERE SET UP THE SOUTHERN CALIFORNIA BIGHT MODEL FOR ANTHROPOGENIC NUTRIENT APPLICATIONS

- Set up the domain with 300 m resolution grid
- Configured model with ocean boundary conditions, forced by 1 km resolution ROMS-BEC simulations
- Compiled datasets of land and atmospheric inputs
- Parameterized, tested and conducted sensitivity analysis on how those inputs are configured

Spatial resolution =300m




*All of this is described in the Kessouri et al. 2021 JAMES article*

doi.org/10.1029/2020MS002296

# We Focused this Talk on "Land-Based Inputs"

*"If you want to talk about numerical modeling to inform nutrient management, then you need to **get the loads right**"*

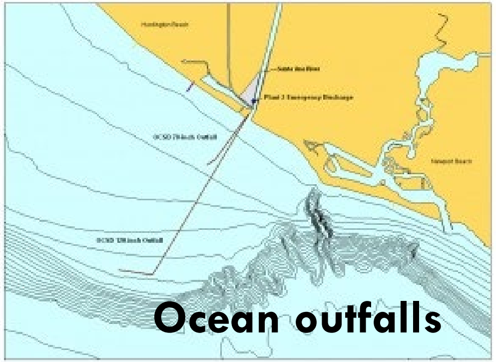
Advice of Dr. Walter Boynton, Chesapeake Bay scientist and long-time advisor to San Francisco Nutrient Management Strategy, 2011 BACWA Workshop

- To "**get the loads right**", that not only involves what data were used as inputs to the model to represent the loads, but also how they are configured in the model

# Goals of This Talk

- Provide an overview of approach to compile terrestrial and atmospheric forcing data
  - Summarize those inputs to provide important context for today's discussion
- Describe how inputs were configured in the model
  - Including testing and sensitivity analysis to "get the loads right"

# We Compiled two decades of data on Nutrient and Carbon inputs from four Pathways




*Sutula et al. 2021 provides detailed methods and findings (doi.org/10.1029/2020MS002296)*

# Atmospheric Pathways of Nutrients and Ambient $CO_2$ are based on observations or models

**Wet and Dry Atmospheric deposition**

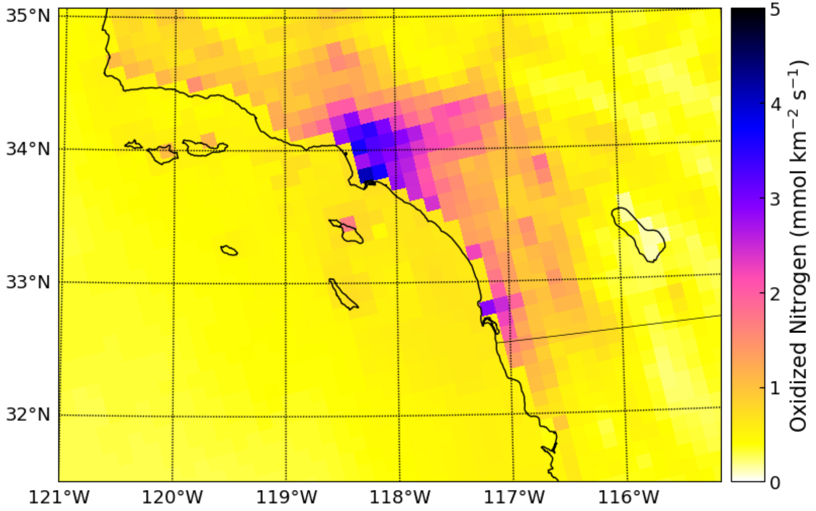
EPA Community Multi-scale Air Quality Model (CMAQ)

**Atmospheric $CO_2$ concentrations**

Global CO2 at interpolated from monthly mean data from Mauna Loa Observatory, Hawaii

ROMS-BEC simulations of "Ocean only" already includes influence

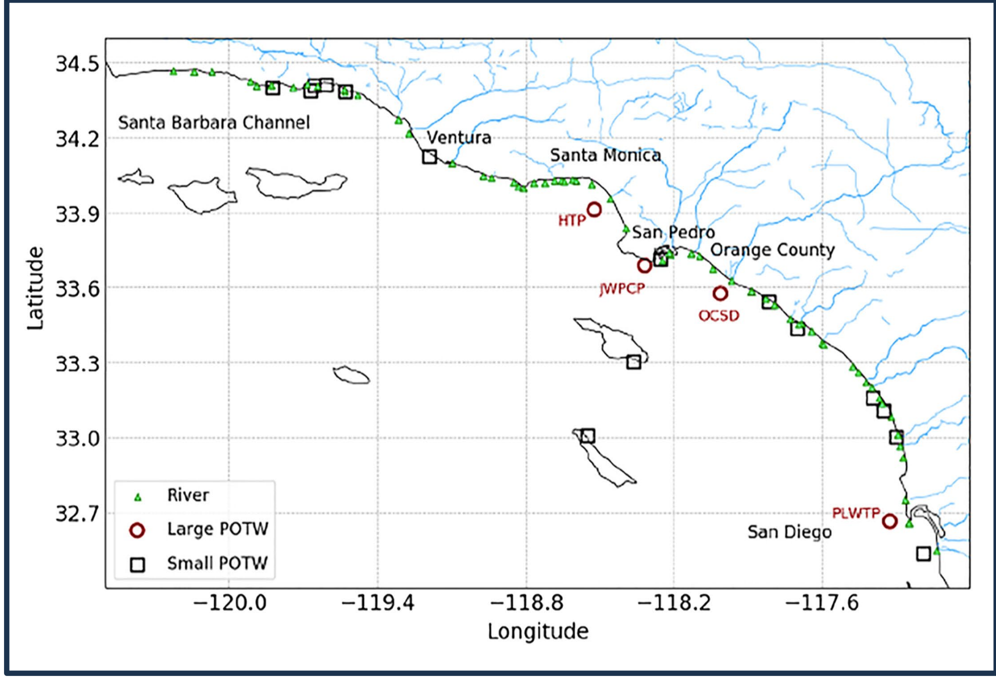
### CMAQ Predicted Atmospheric Nitrate Deposition




Wet and dry atmospheric deposition constituents

- Ammonia
- Nitrate
- Carbonate system (Alkalinity, pH)

# Pathways of Land-based Inputs of Nutrients Are Well Documented by Discharger Monitoring Programs




- **19 POTW Ocean outfall**
  - 50 Years of monthly data
  - Targeted sampling for selected constituents

- **Surface water runoff from 75 rivers**
  - 20-year dataset of daily river flow and seasonal mean constituents at “mass loading” stations
  - Used modeling to estimate flow and loads from unmonitored watersheds and to predict “natural background loading”

# Targeted Constituents Were Compiled at Daily to Monthly Timescales over a 20-year period (1997-2017)

## *THREE CLASSES OF CONSTITUENTS*

Discharge

Temperature

Conductivity

**Dissolved Inorganic Nutrients and Carbon**

Nitrate

Ammonium

Phosphate

Silicate

Dissolved Fe

Carbonate system (pH/Alkalinity)

**Organic Matter**

Organic C

Organic N

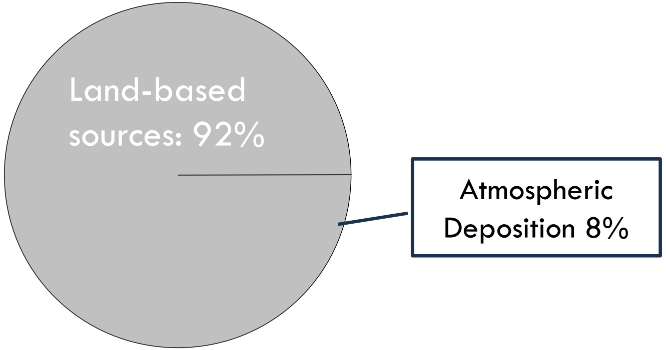
Organic P

BOD

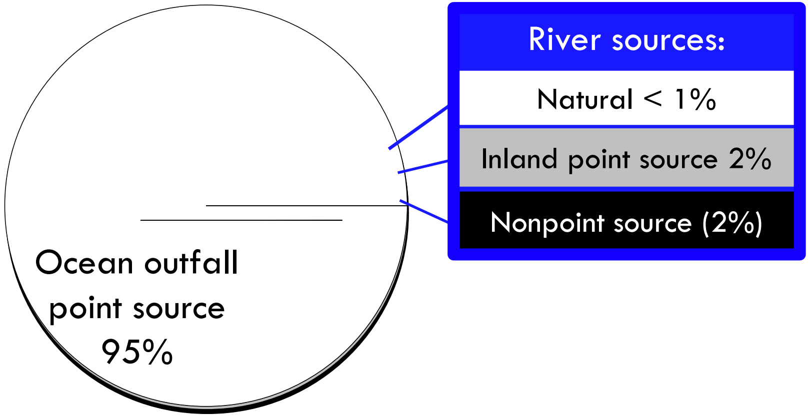
To assure parity among sources and pathways, we filled in gaps: 1) with special studies or 2) made assumptions when necessary to infer concentration of missing parameters

# Synthesis of Inputs: Relative Importance of Sources to the Bight

- **On the continental shelf, land-based sources of total nitrogen are an order of magnitude higher than atmospheric deposition**

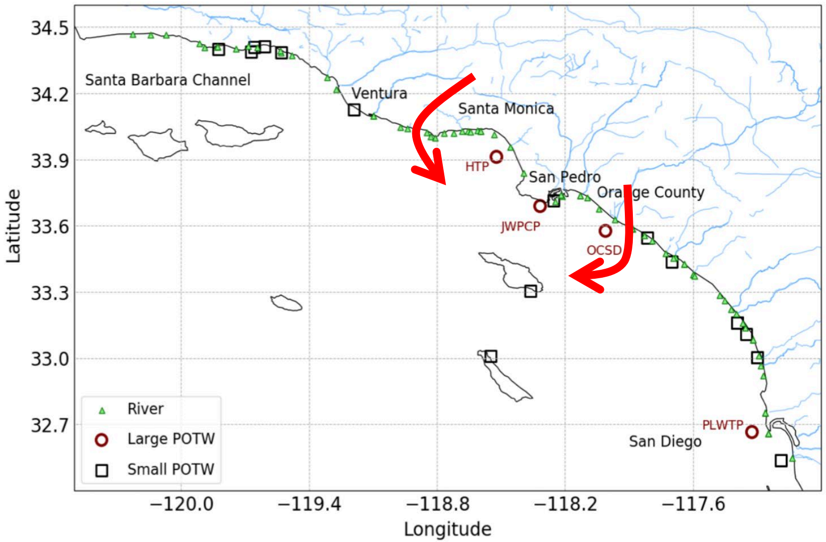



- **Relative distribution of land-based inputs**
  - Point sources of 97% of total nitrogen loads to the SCB, 95% to ocean outfalls
  - Riverine nonpoint sources are 2%
  - Natural sources are < 1%

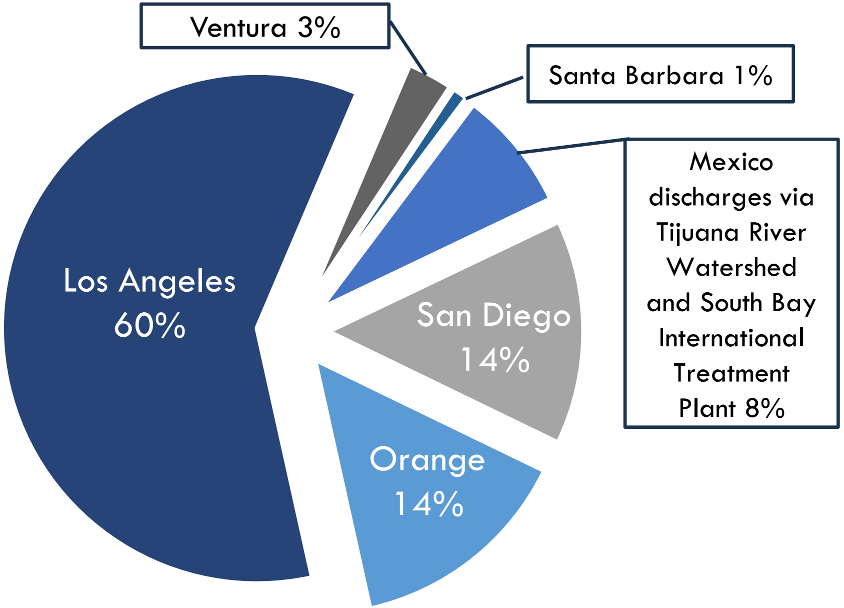


# Synthesis of Inputs: Spatial Distribution of Inputs to U.S. Coastal Waters?

- Los Angeles and Northern Orange Counties have ~70% of total inorganic nitrogen loads




## Relative Percent of Inorganic Nitrogen Loads (2013-17) Discharged to US Coastal Waters

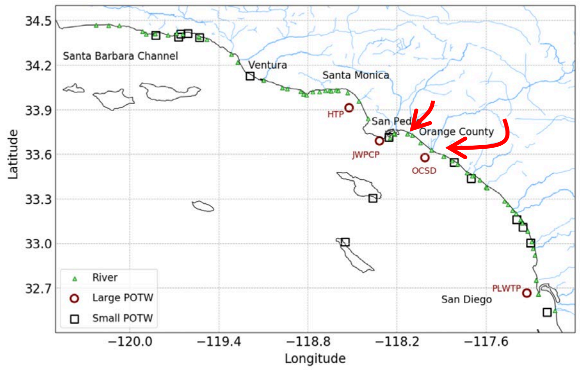



- Mexican transboundary inputs via Tijuana R. watershed (8%) are included in our published studies
  - An additional 5% enters south of the border, effects of which have not yet been published

# OVER THE PAST 20 YEARS, TOTAL INORGANIC NITROGEN LOADS FROM U.S. SOURCES HAVE DECLINED SLIGHTLY

OC Coast declined due to nutrient management by OCSD

| Region | All Outfall DIN Loads (Metric Tons /day) | | | River DIN Loads (Metric Ton/day) | | |
|---|---|---|---|---|---|---|
| | 1997-2000 | 2013-2017 | % change | 1997-2000 | 2013-2017 | % change |
| South San Diego | 23 | 22 | -4% | 0.9 | 1.3 | +42% |
| North San Diego | 7 | 6 | -7% | 0.21 | 0.1 | -37% |
| Orange County | 33 | 19 | -43% | 0.9 | 0.6 | -32% |
| San Pedro | 39 | 42 | +8% | 11 | 1.8 | -83% |
| Santa Monica Bay | 37 | 38 | +3% | 0.15 | 0.13 | -9% |
| Ventura | 2 | 2 | +28% | 1.6 | 1.7 | +8% |
| Santa Barbara | 1 | 1 | +5% | 0.2 | 0.1 | -44% |
| US SCB Total (inc. Islands) | 143 | 132 | -8% | 15 | 5.9 | -61% |




LA River and San Gabriel River represent 73% of total riverine loads to the SCB.

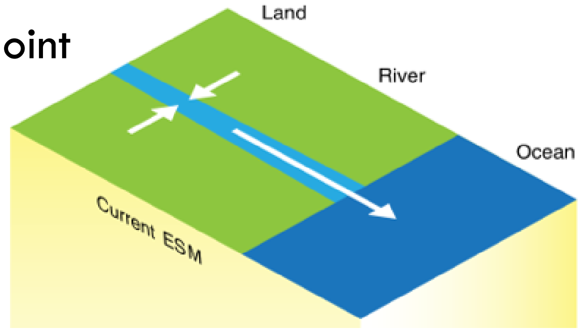
Reductions in those rivers from plant upgrades to advance nutrient management drove riverine trends for entire region.

# GOALS OF THIS TALK

- Provide an overview of approach to compile terrestrial and atmospheric forcing data
  - Summarize those inputs to provide important context for today's discussion
- Describe how inputs were configured in the model
  - Testing and sensitivity analysis to "get the loads right"

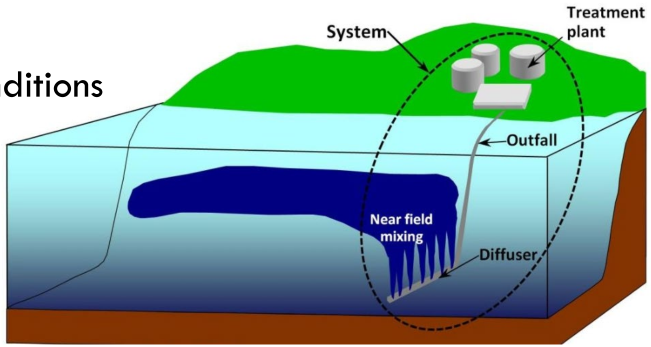
# Configuration of Land-based Inputs into ROMS-BEC

- Rivers/estuaries and ocean outfalls are all represented as point sources in the model
  - Locations and depths (outfalls) are based on data




- ROMS-BEC simulations at 300 m resolution do not resolve nearfield mixing of outfall plumes
  - Parameterized initial dilution of plumes, based on data
  - Conducted sensitivity analysis to assure it works in a variety of conditions

- Dilution approach accounts for location of plume mixing
  - River plumes spread and mix in upper surface waters
  - Outfall pipes discharge offshore in subsurface, some above and some below the thermocline




Schematic from Roberts et al. (2010) showing an outfall pipe and diffuser

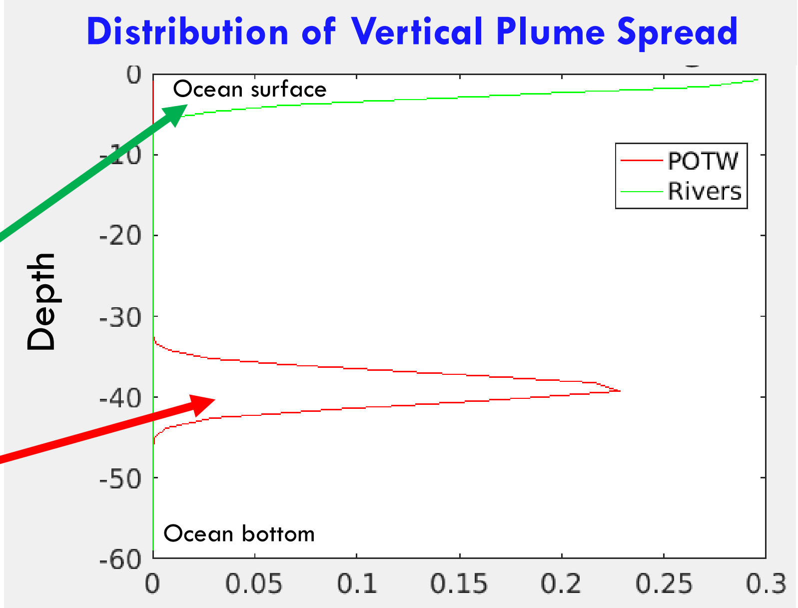
# Plumes Are Diluted Along the 60 Vertical Cells Representing Ocean Depth

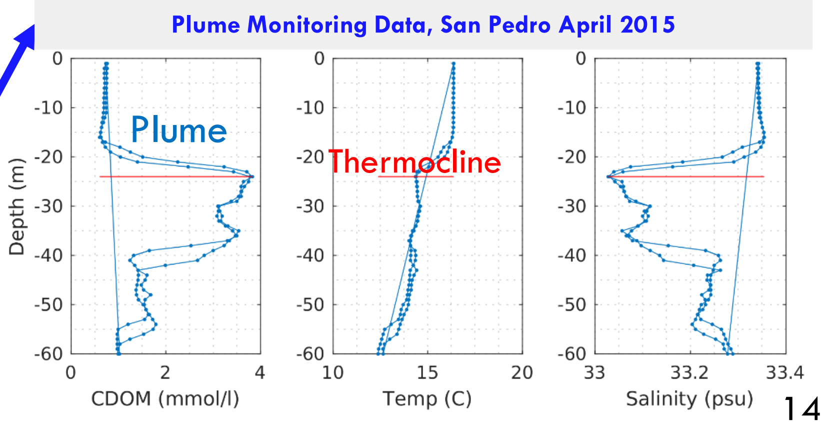
**Riverine inputs were distributed in top 3 meters**

**Outfall plumes were distributed as a shape function roughly 10 meters above the pipe**

- This establishes an initial rise and spread from the pipe
- ROMs physical processes then cause the plume rise, mix and spread to point of neutral buoyancy
  - Stops at thermocline, if stratified
  - Mixes all the way to the surface, if not

*Decision was informed by looking at hundreds of POTW plume monitoring profiles*



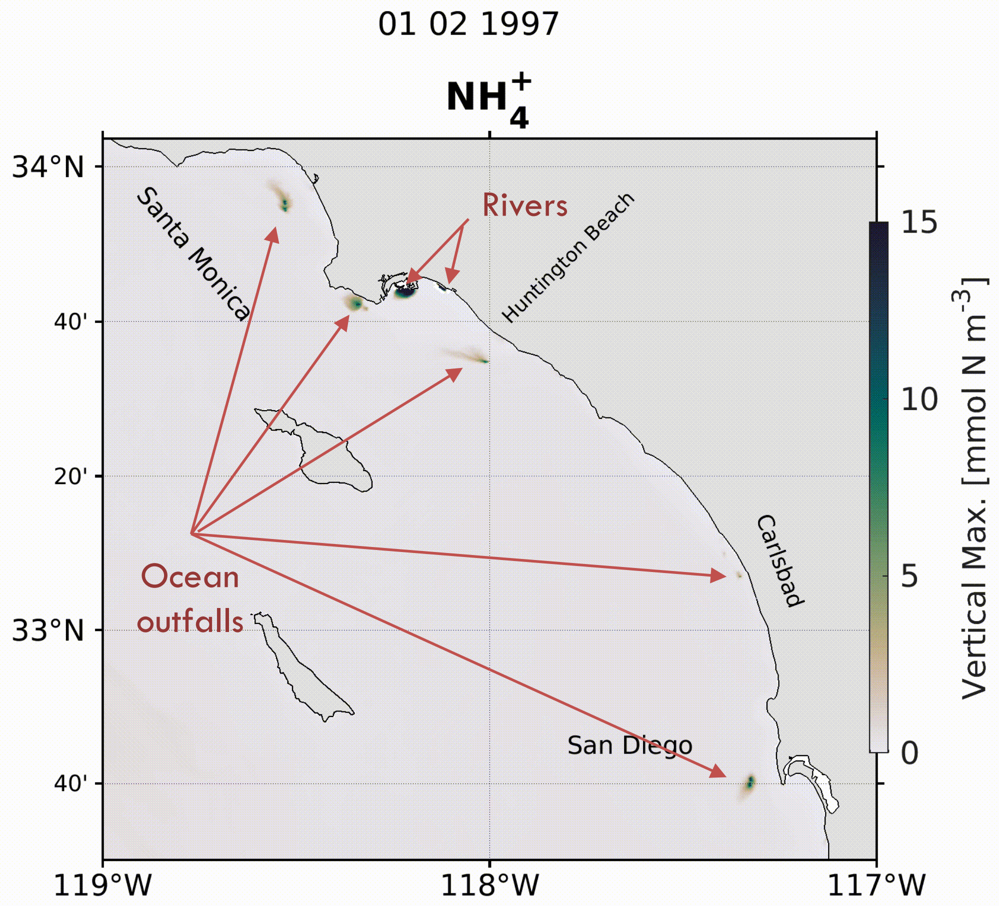
# Sensitivity analysis on Approach to Vertical Dilution

## What was tested?

- Where the initial height of the plume spreading occurs (30-40-50-60m …)
  - In variable ocean states (e.g. stratification, mixing)

## What were my conclusions?

- Results were insensitive to initial height of plume spreading
  - The diffused plume always rises to the thermocline when the ocean is stratified
  - A well mixed ocean brings the plume to the surface
  - What is discharged to the surface, spreads in the surface (rivers, some small POTWs)




# Wrapping Up...

## This simulation Shows How Plume Dispersion Looks When Implemented in the Model

## QUESTIONS?

## THANK YOU!

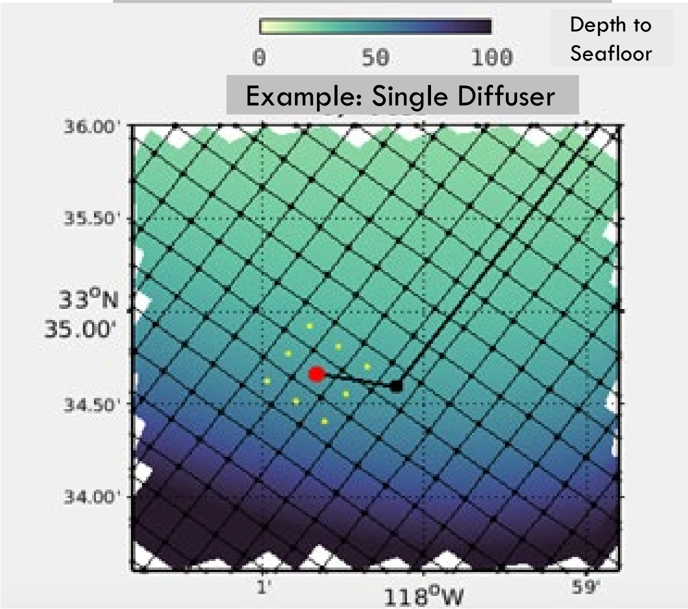
# Plumes of large POTWs (> 100 MGD) Required Horizontal Initial Dilution

### Fraction (F) of volume flux per horizontal grid cell for a single diffuser, where $\sum F = 1$

| | | |
|---|---|---|
| 0.25/9 | 1/9 | 0.25/9 |
| 1/9 | 4/9 | 1/9 |
| 0.25/9 | 1/9 | 0.25/9 |

- Approach matches observations of CDOM and ammonium in plumes
- Prevents high gradients in single cells that will cause model blow up

Schematic of How Outfall Effluent is Distributed Horizontally




***Horizontal Spreading of Small POTWs occurred within a single cell***

# HOW DOES MODEL CAPTURE OCEAN FORCING FROM 1 KM SCALE

- Smaller grid captures the effects of climate cycle from 1 km grids. Mercator seems to reflect those climate features.
- Boundary conditions are calculated daily and the effects from larger ocean can be simulated for any dynamic longer than a few days.
- One-way offline downscaling is based Orlanski scheme for the baroclinic mode (Marchesiello et al., 2001) and a modified Flather scheme for the barotropic mode (Mason et al., 2010) to minimize wave reflection at the open boundaries of the regional domain and to minimize artifacts.
  - Multiple steps before applying the downscaling, parent and child grids are interpolated matching the mask and topography.
  - A normal velocity correction is applied to ensure volume conservation.
- Mercator to ROMS-- corrections have been applied for temperature and salinity profiles from WOD to reduce biases in Mercator. Similar corrections have been applied for BGC tracers (nutrients, O2, OM).
- We used daily boundary forcing to ensure the transition of major mesoscale features from parent to child grid. Tides were only applied in the smaller domain.