Microplastic Transport in an Urban Estuary

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UC DAVIS CENTER FOR WATERSHED SCIENCES

SFEI AQUATIC SCIENCE CENTER
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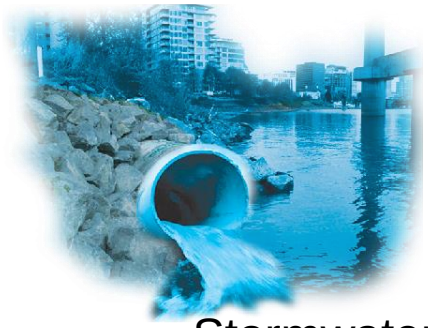
5 GYRES
SCIENCE TO SOLUTIONS

San Francisco Bay Microplastics Project

GORDON AND BETTY MOORE FOUNDATION

Load Sampling

Wastewater



Stormwater

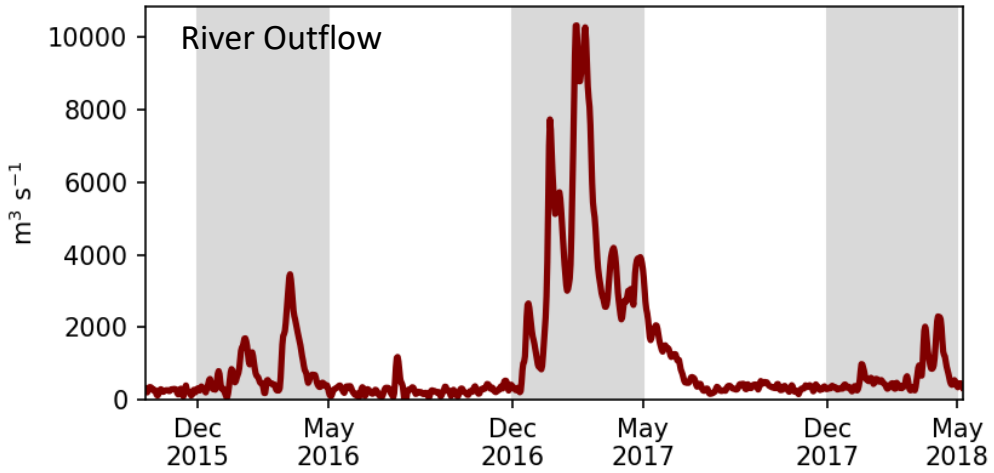
Transport Model

Coastal Sampling

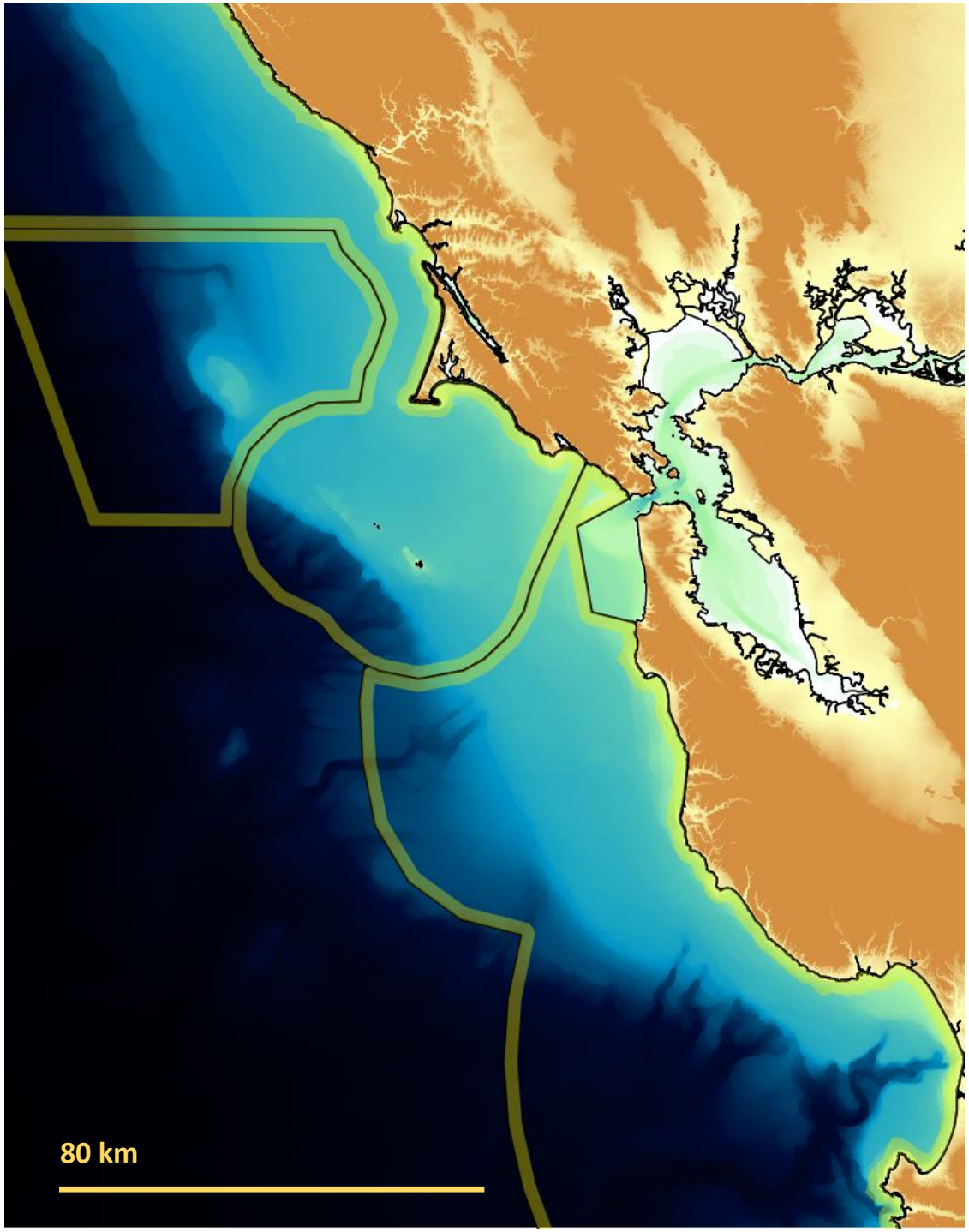
Bay Sampling

San Francisco Bay and Coastal Waters

- 40% of California drains into Bay
- Residence times of days to months
- Wet season / dry season

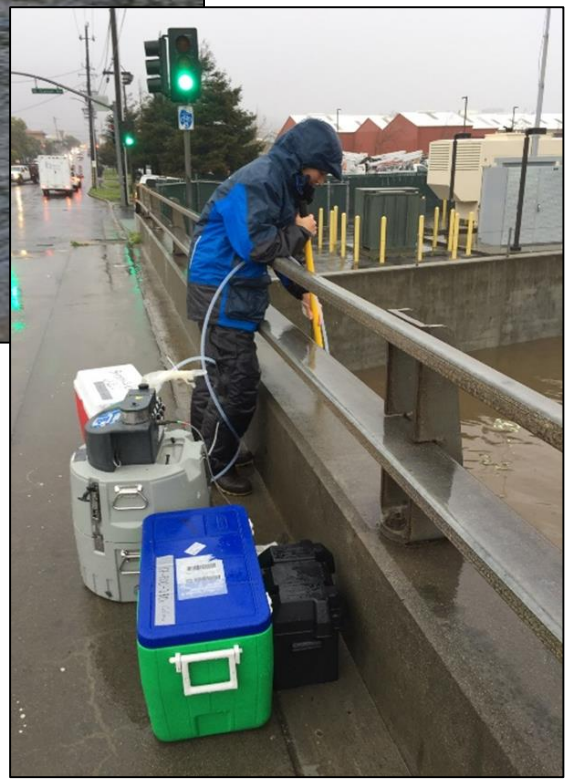


- Marine sanctuaries
- Transport by tides, estuarine circulation, coastal current, seasonal upwelling



Sampling Loads

Stormwater

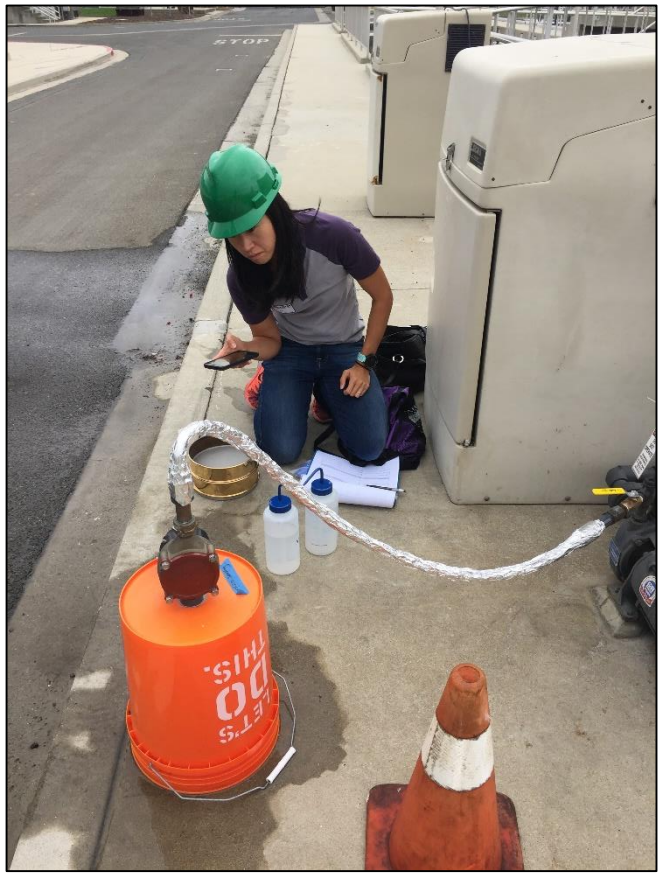


12 watersheds

Sample around peak of hydrograph

Sieve down to 125 µm

Wastewater

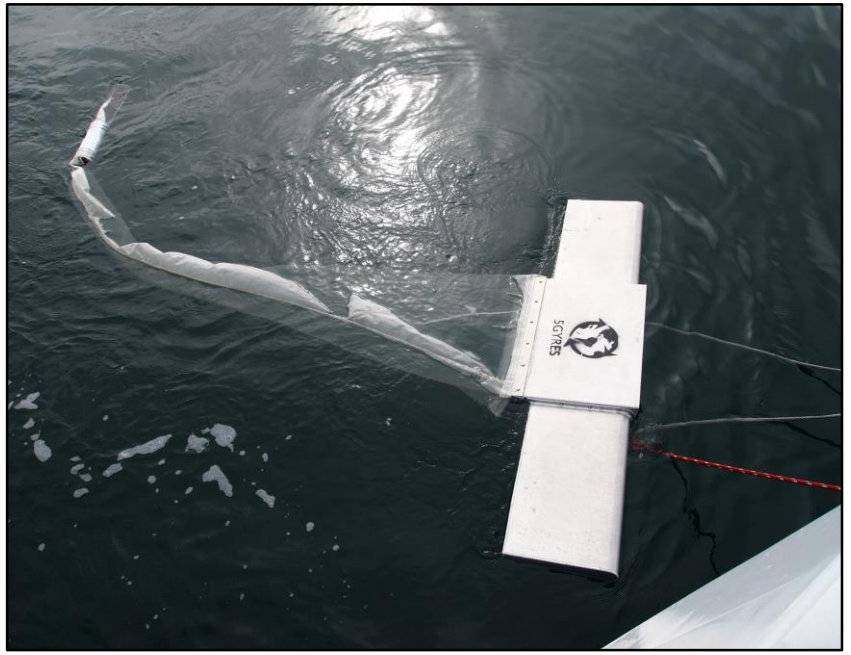


Treated effluent from 8 plants

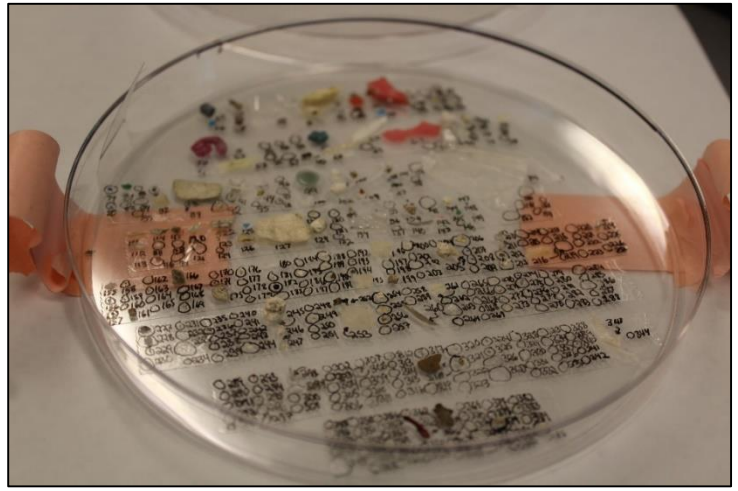
Sieve down to 125 µm

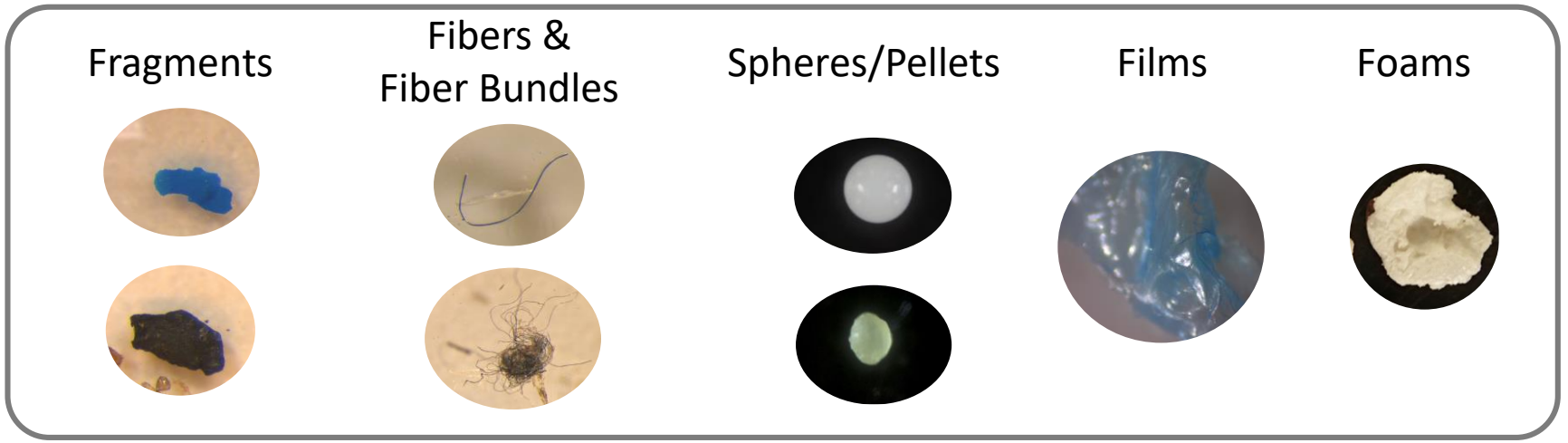
Sampling Ambient Water

- Manta Trawl
  - Larger than 355 μm
- Bay and coastal ocean
- Dry weather and wet weather
- 58 samples, 28 sites



Particle Characteristics





- Record length, width, color
- Include non-plastic anthropogenics
  - Rubber
  - Glass

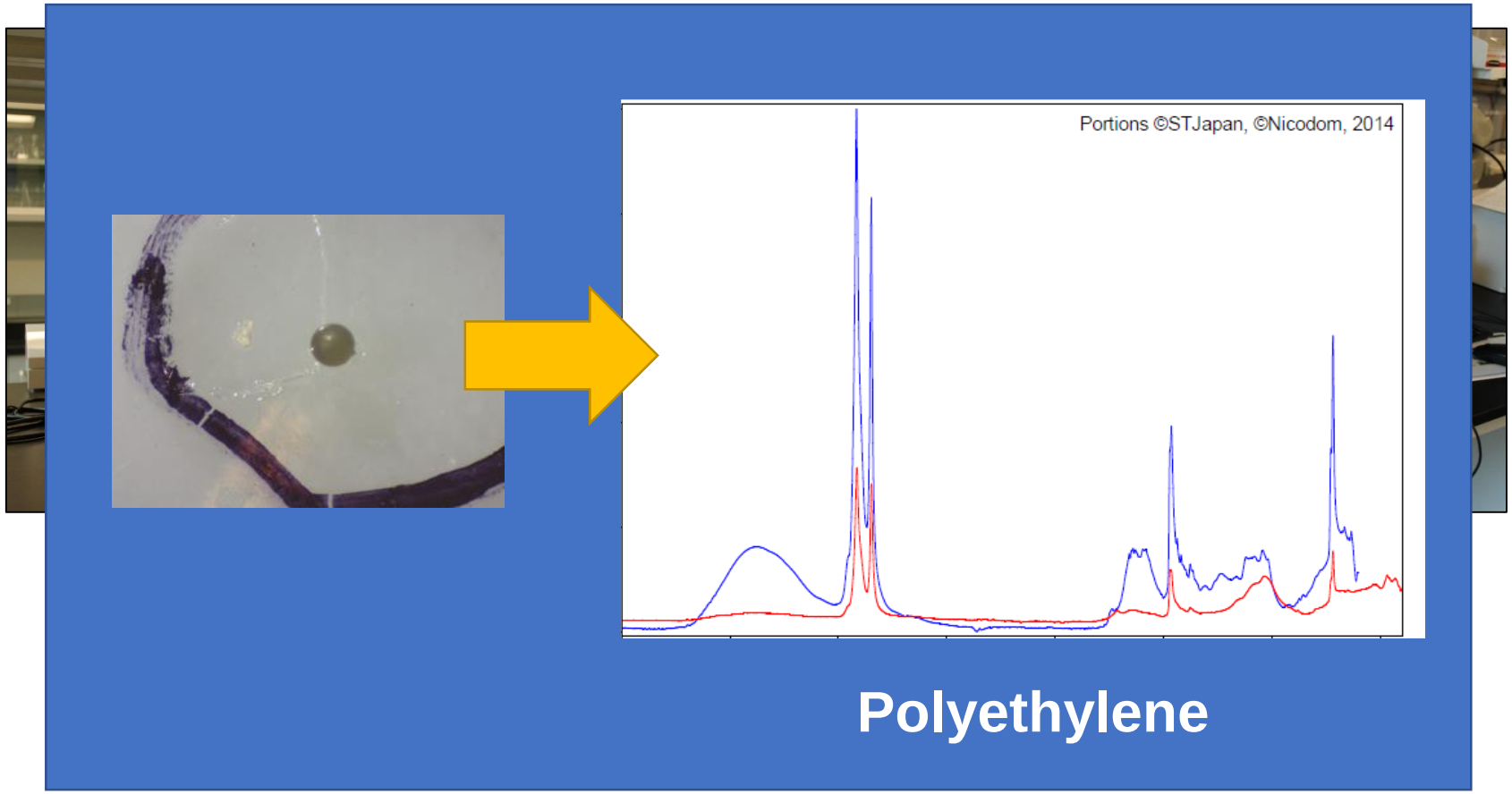
Chemical Composition

FTIR

- Particles >250µm

Raman

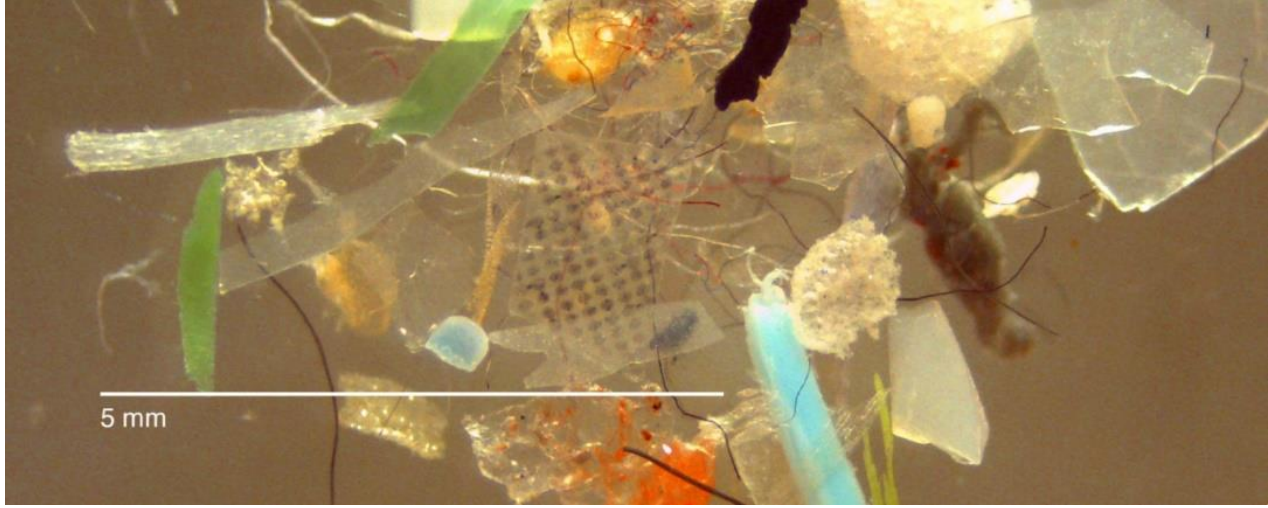
- Particles <250µm



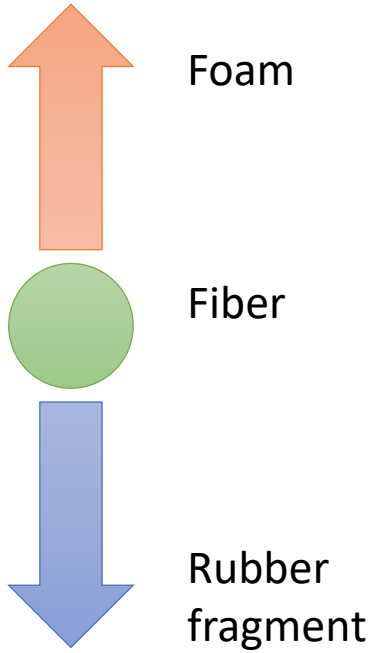
Microparticle Transport

- Like sediment
  - Characteristic settling velocity
- *except…*
  - Composition, shape

    range of settling and rise velocities
  - Deposition dynamics uncertain
  - Fragmentation, biofilms



Variety of composition, size and morphology



Estimation of Settling Velocity

- Method of Walschlägger and Schüttrumpf, 2019

ENVIRONMENTAL Science & Technology

Article

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Effects of Particle Properties on the Settling and Rise Velocities of Microplastics in Freshwater under Laboratory Conditions

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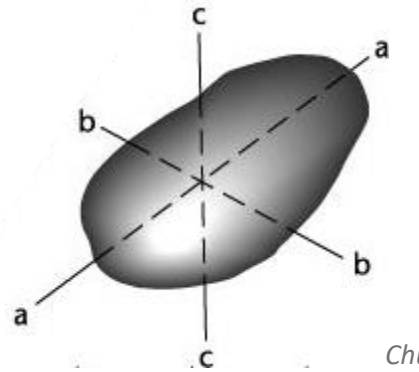
Supporting Information

ABSTRACT: Microplastic (MP) contaminates terrestrial, aquatic, and atmospheric environments. Although the number of river sampling studies with regard to MP concentrations is increasing, comprehension of the predominant transport processes of MP

Density: from literature based on plastic type
Dimensions: 3 diameters, a>b>c



Church, 2005

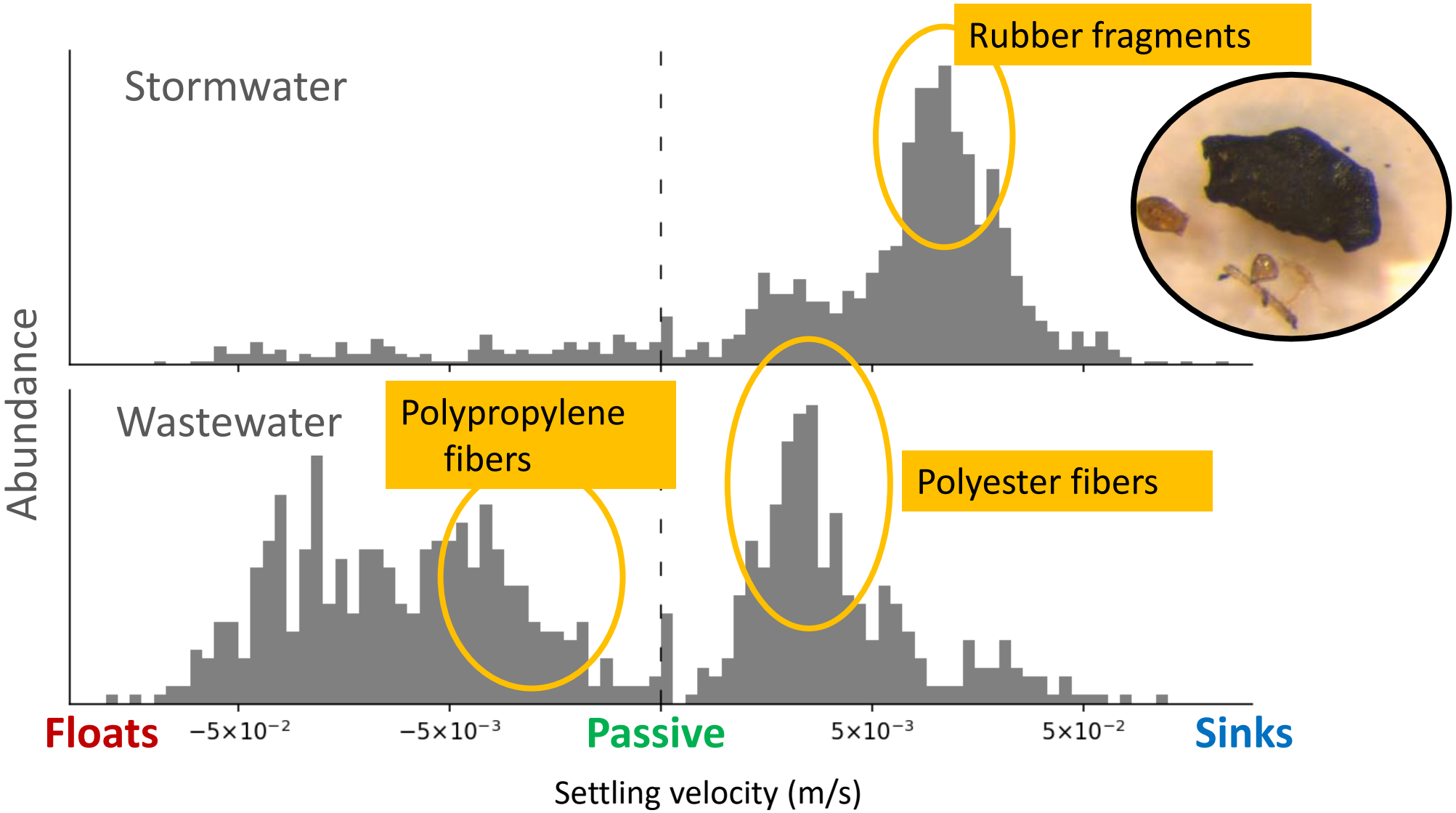
Roundness: Powers – angular to round
Morphology: Fibers separately calculated

w_s: settling or rising velocity

Does it sink or float?

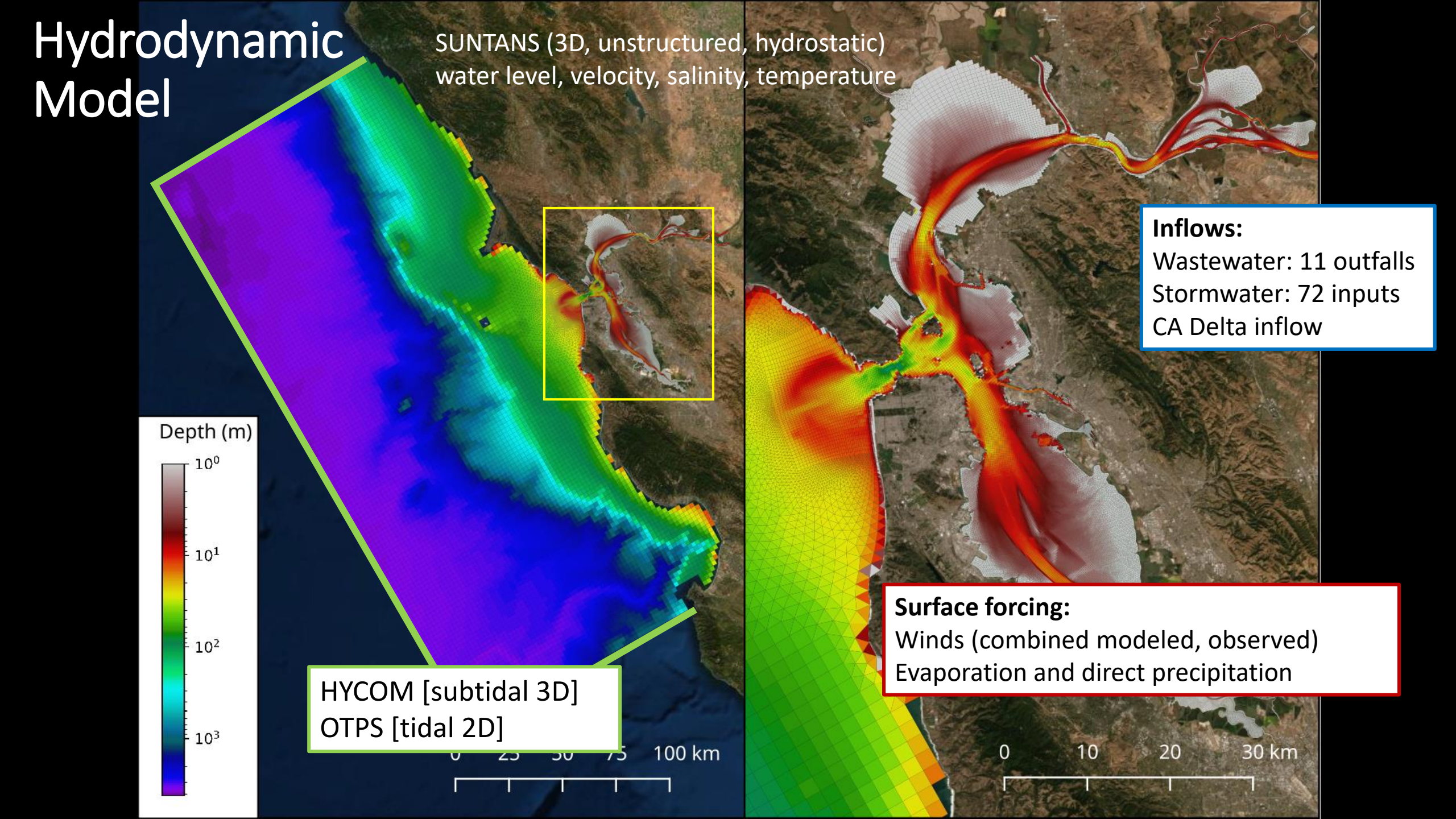
Mean:
9.2 particles/l

Mean:
0.063 particles/l



Hydrodynamic Model

SUNTANS (3D, unstructured, hydrostatic)
water level, velocity, salinity, temperature



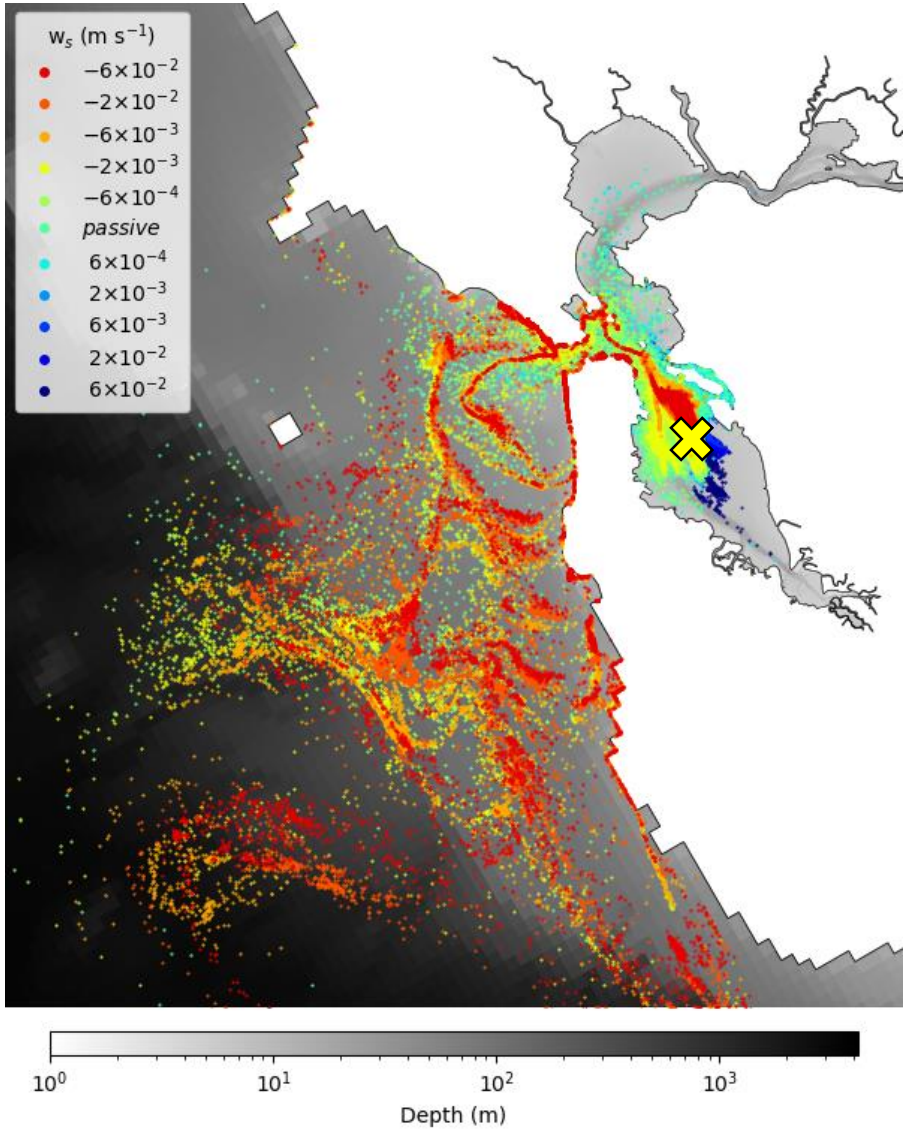
Inflows:
Wastewater: 11 outfalls
Stormwater: 72 inputs
CA Delta inflow

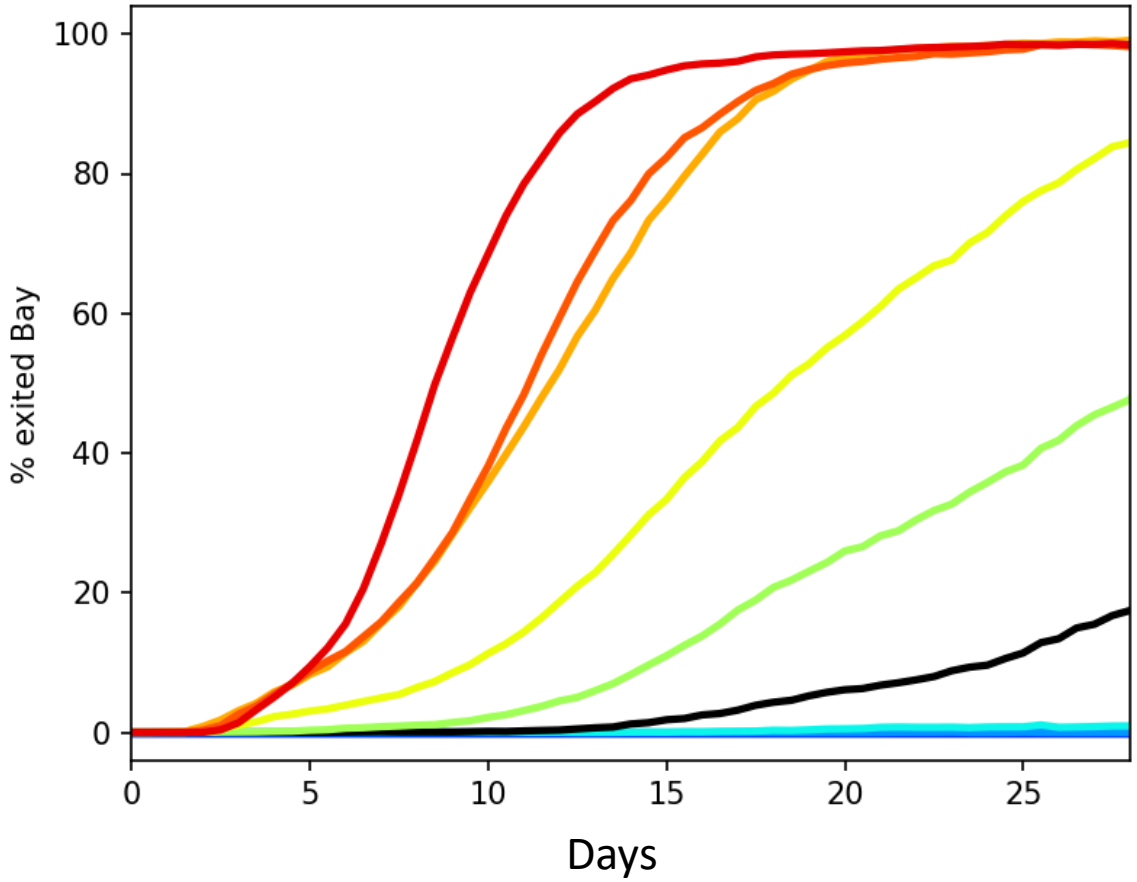
Surface forcing:
Winds (combined modeled, observed)
Evaporation and direct precipitation

Particle Tracking

RED: Rising, 5mm/s
GREEN: Passive
BLUE: Sinking, 5mm/s

Particle Fate: Time Scales





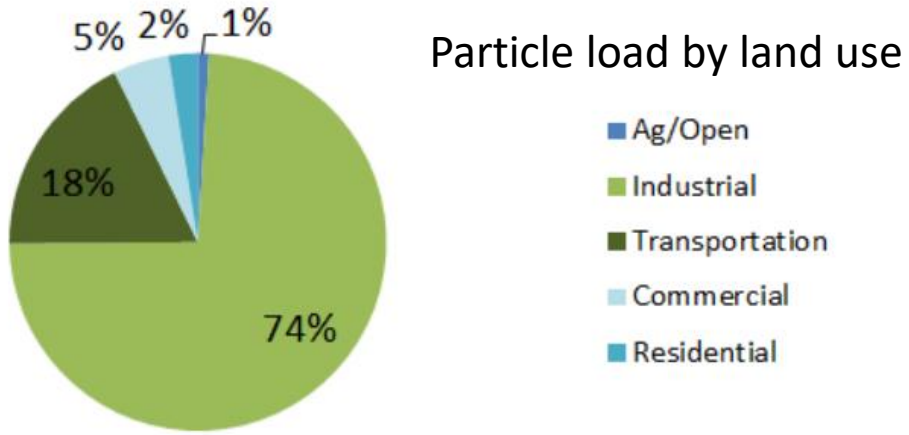
Wastewater Loads

- Measured microparticles in effluent at 8 wastewater treatment plants
- Hydrodynamic model includes outfalls for each
- Loads binned by rising/sinking velocity *±50mm/s, ±5mm/s, ±0.5mm/s, neutral*
- Blank contamination rate calculated per morphology, applied as correction factor

Stormwater Loads

- Sampled 12 watersheds
- Correlated land use data with particle abundance
- Hydrodynamic model includes 41 watersheds
- Load concentration scaled per watershed based on land use
- Distribution of particles types calculated over all stormwater samples

Metrics; coefficients in microparticles/L	*Model 1*
Industrial Coefficient	62
Transportation Coefficient	10
Commercial Coefficient	5
Residential Coefficient	1
Agriculture and Open Space Coefficient	0.1



SFEI, 2019

Predicted Surface Concentration

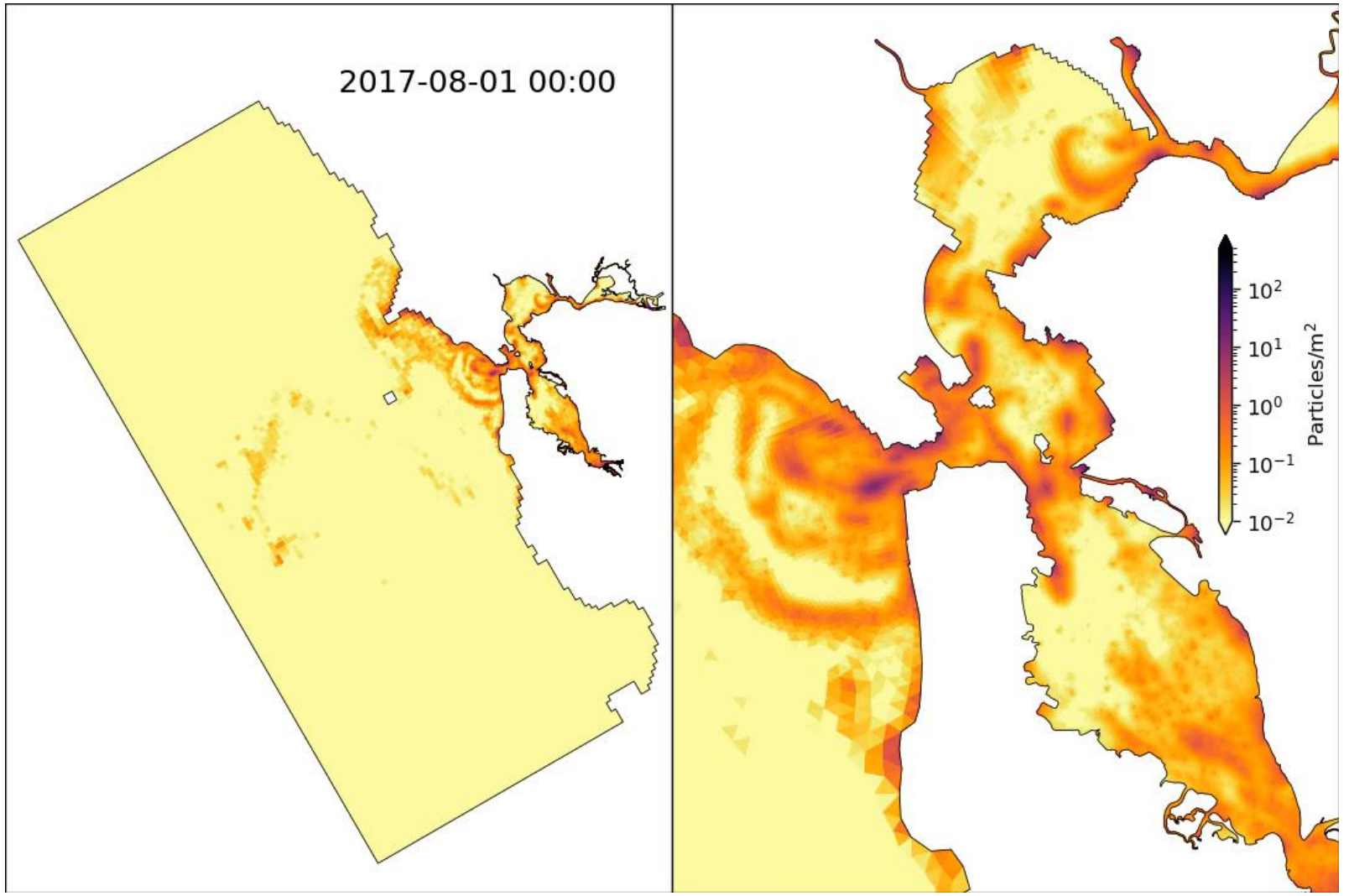
Surface concentration

Track particles for 60 days

Concentrations span orders of magnitude.

Spatial variability
- Fronts, shorelines

Temporal variability
- Tidal advection
- Vertical mixing: tides, wind



Model Skill

- Omit fibers from comparison (blank contamination and limited data)
- Spearman rank correlation: $\boldsymbol{\rho}$=0.73, N=65, $p \ll 0.0001$
- Observations are approximately log-normal
- Pearson $\boldsymbol{r}$ after log transform r^2=0.49, N=64, $p \ll 0.0001$

- Magnitude overpredicted by a large factor: 15

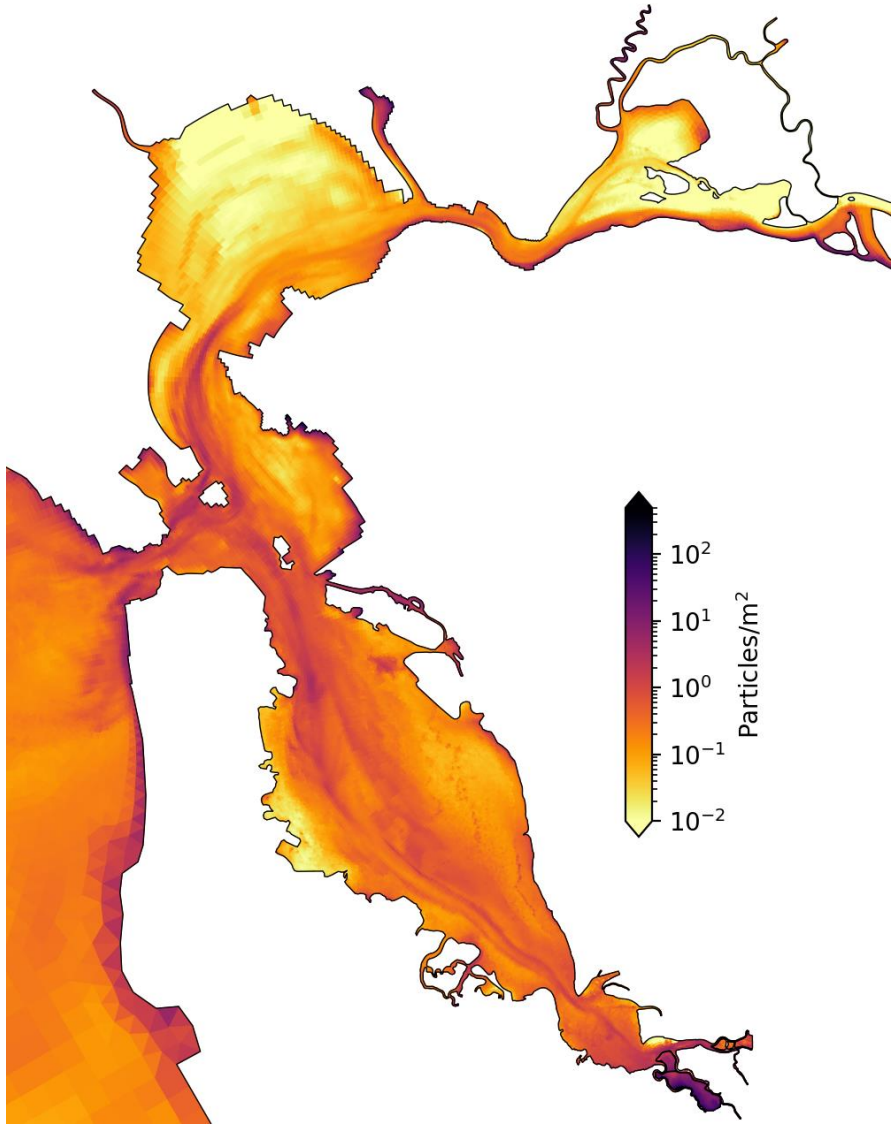
Overpredicted Magnitude

Open water surface concentrations lower than loads imply

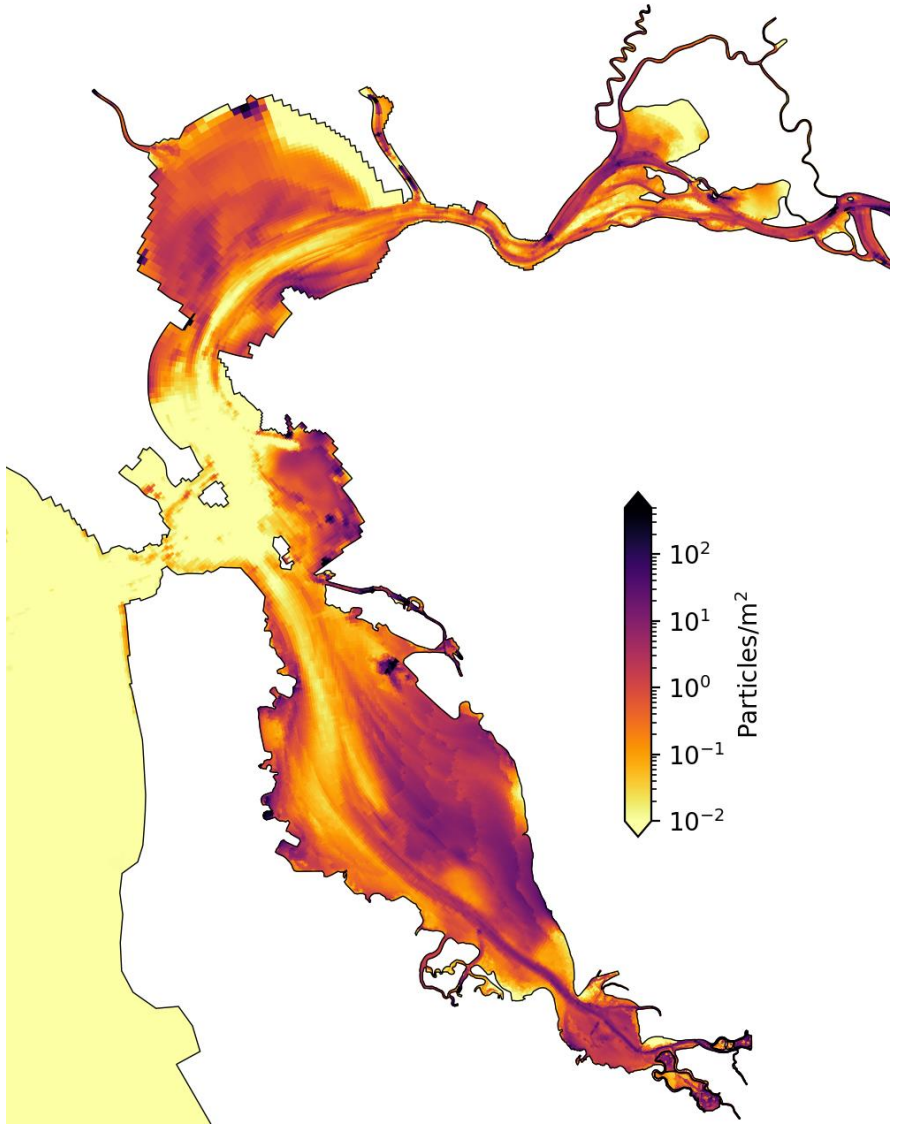
Potential explanations:

- Loss between point of stormwater measurement and open Bay
- Stormwater concentration not constant
- Particle beaching and deposition in Bay
- Effect of sieve sizes: 355 μm for surface water, 125 μm for loads
- Biofouling, fragmentation
- Overestimate rising velocities
- Model errors

Dry weather particle distributions



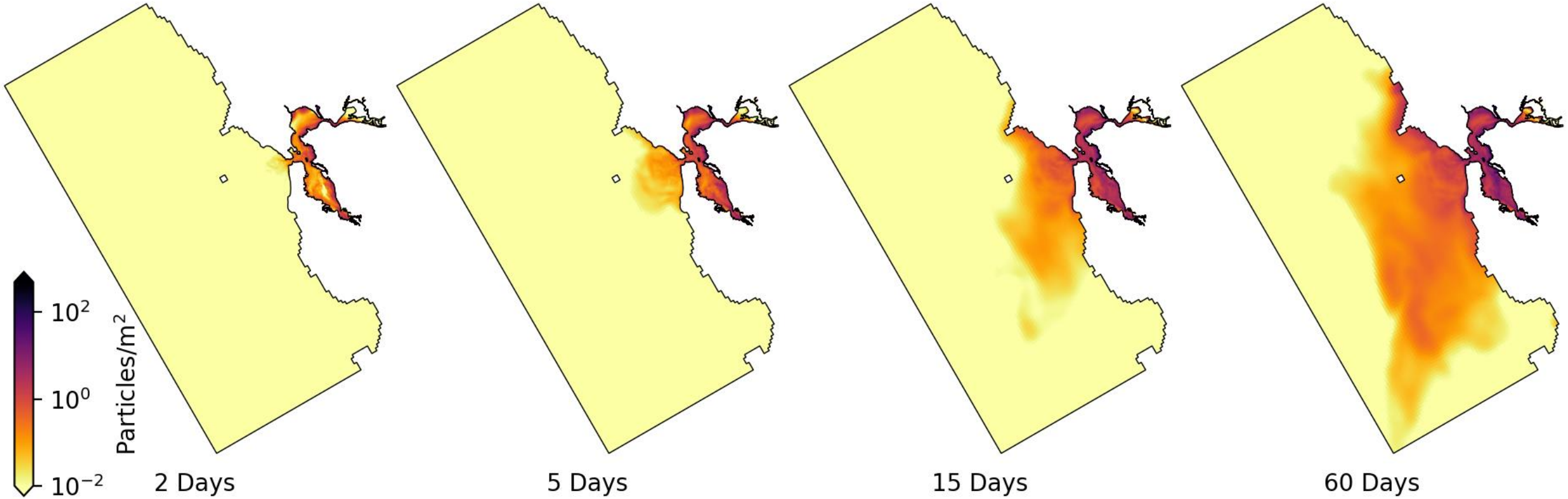
Surface



15 day average

Bed

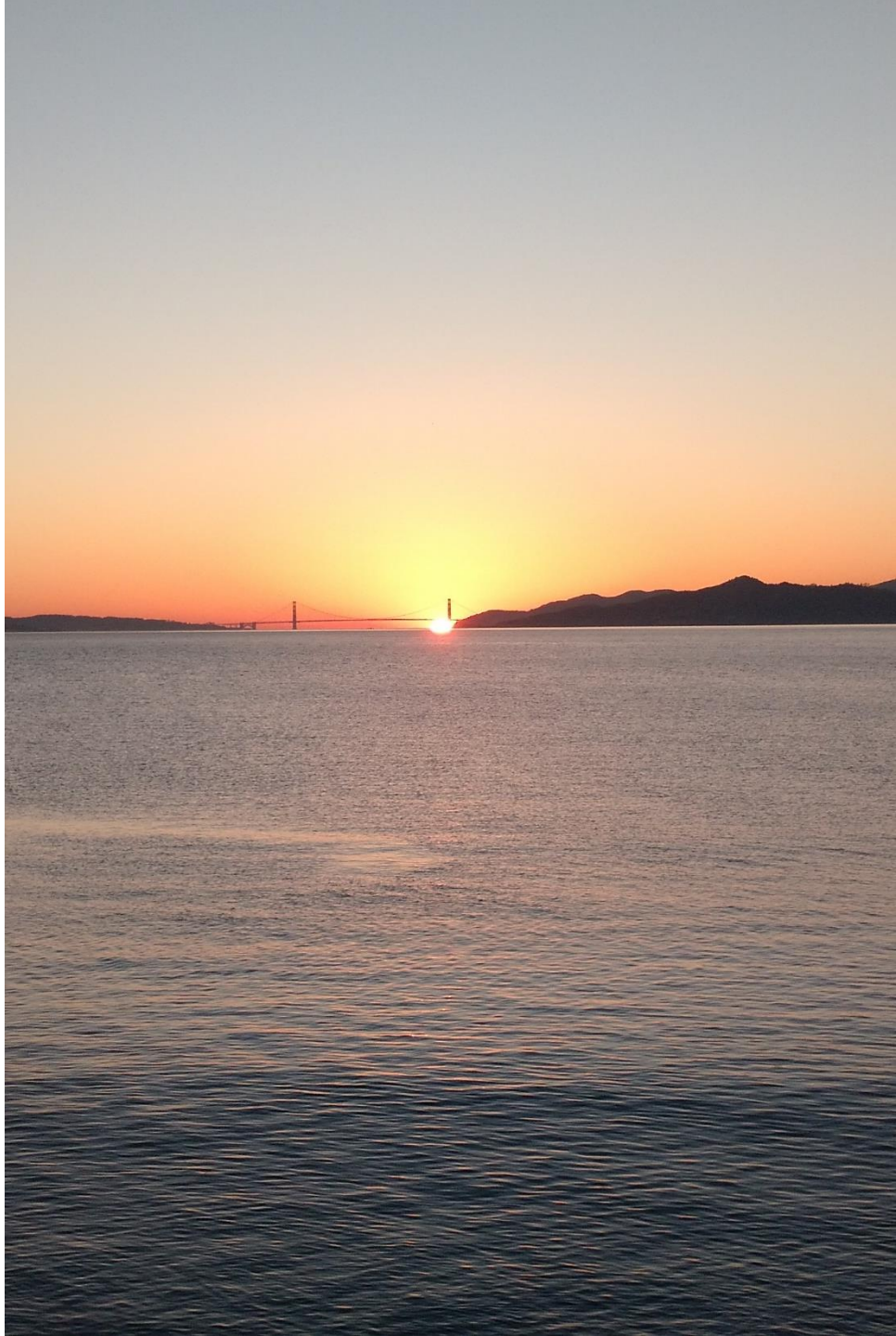
Distribution by Max Age – Surface



Surface concentration Wet season 15-day average

Summary

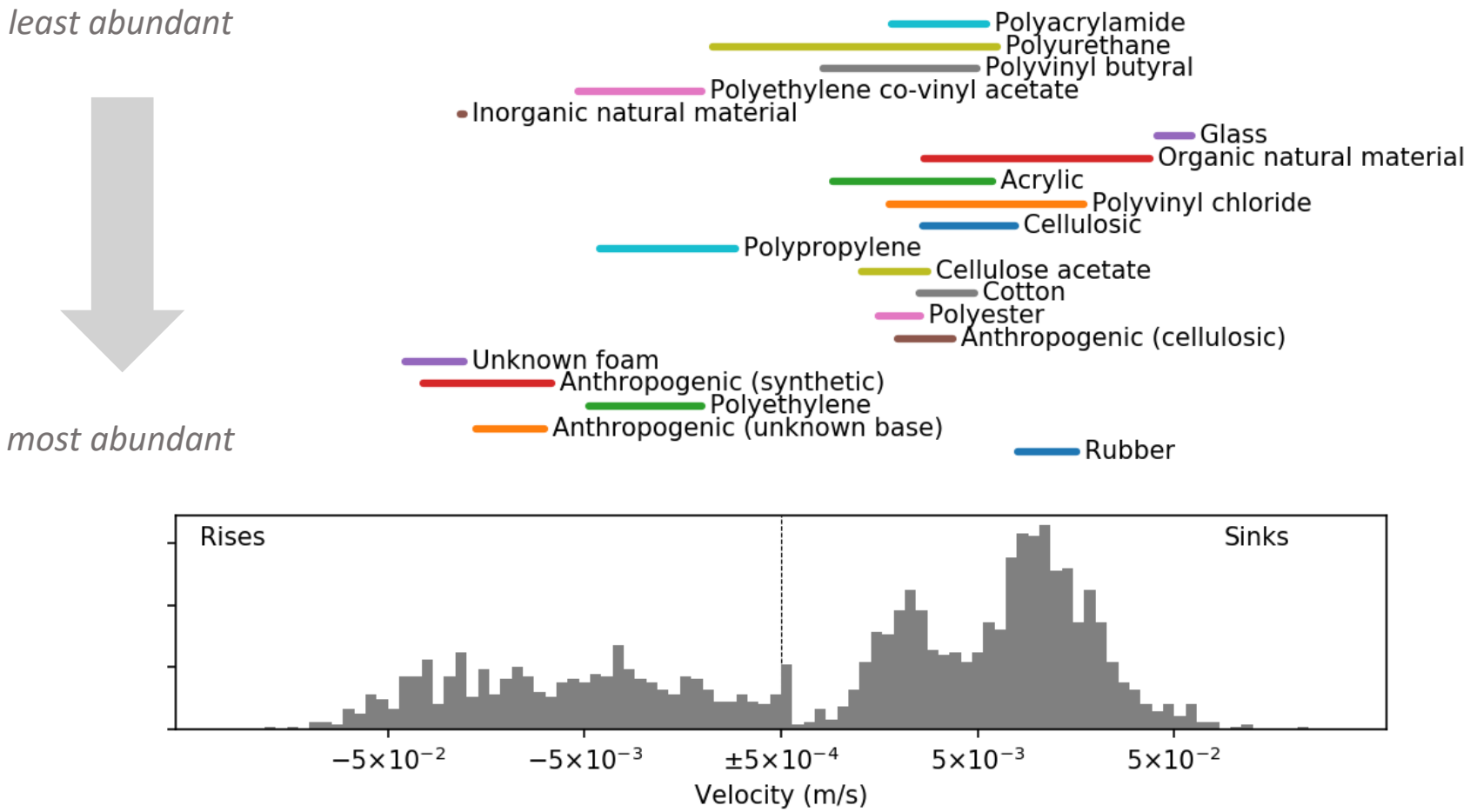
- Stormwater particles primarily sink, Wastewater more floating particles
- Fate dictated by buoyancy:
  - Buoyant particles can reach the National Marine Sanctuaries
  - Sinking particles retained in the Bay
- Loads imply greater surface abundance than measured
- Interaction of buoyant particles with estuarine fronts



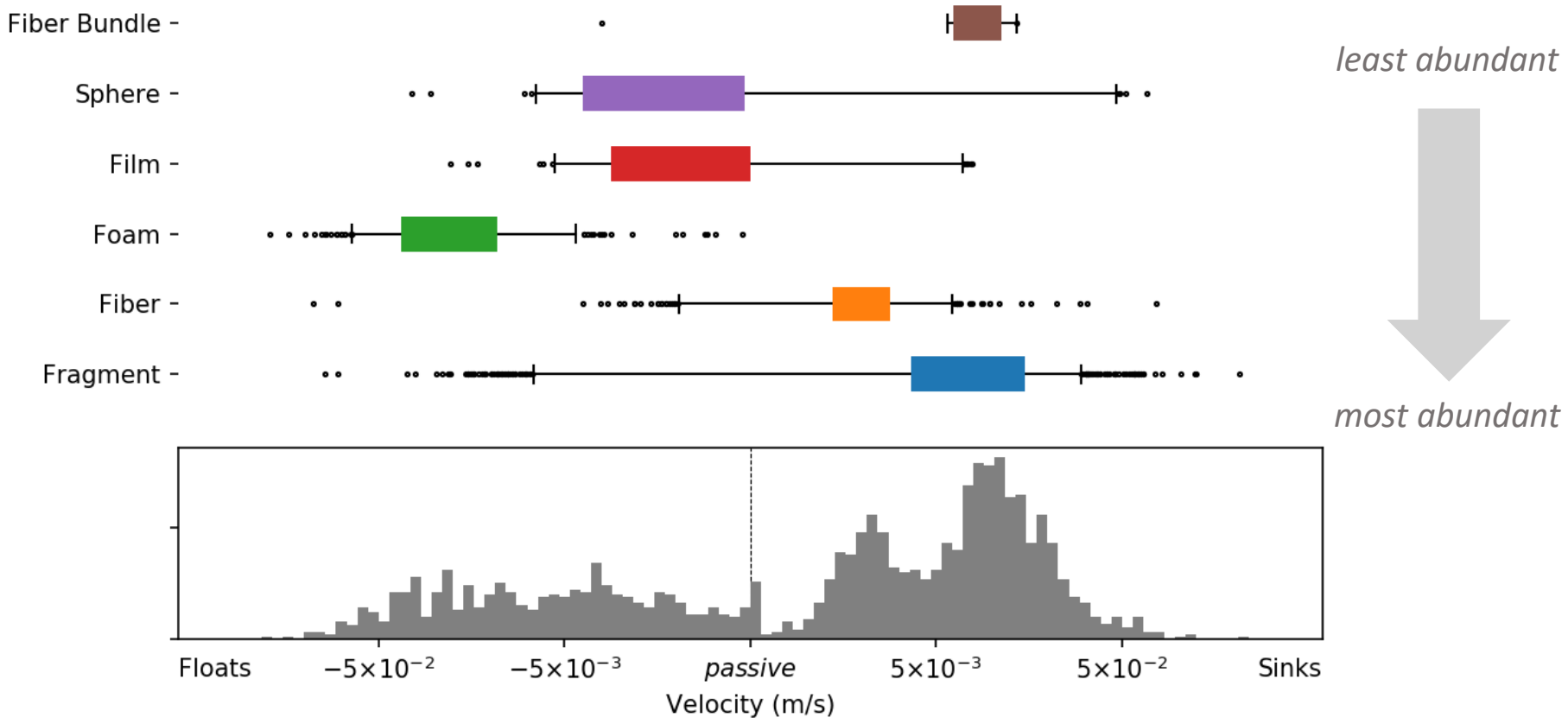
Additional Slides

Rise/Settling Velocity: Composition

20 most common particle types in stormwater and wastewater samples



Settling Velocity: Morphology



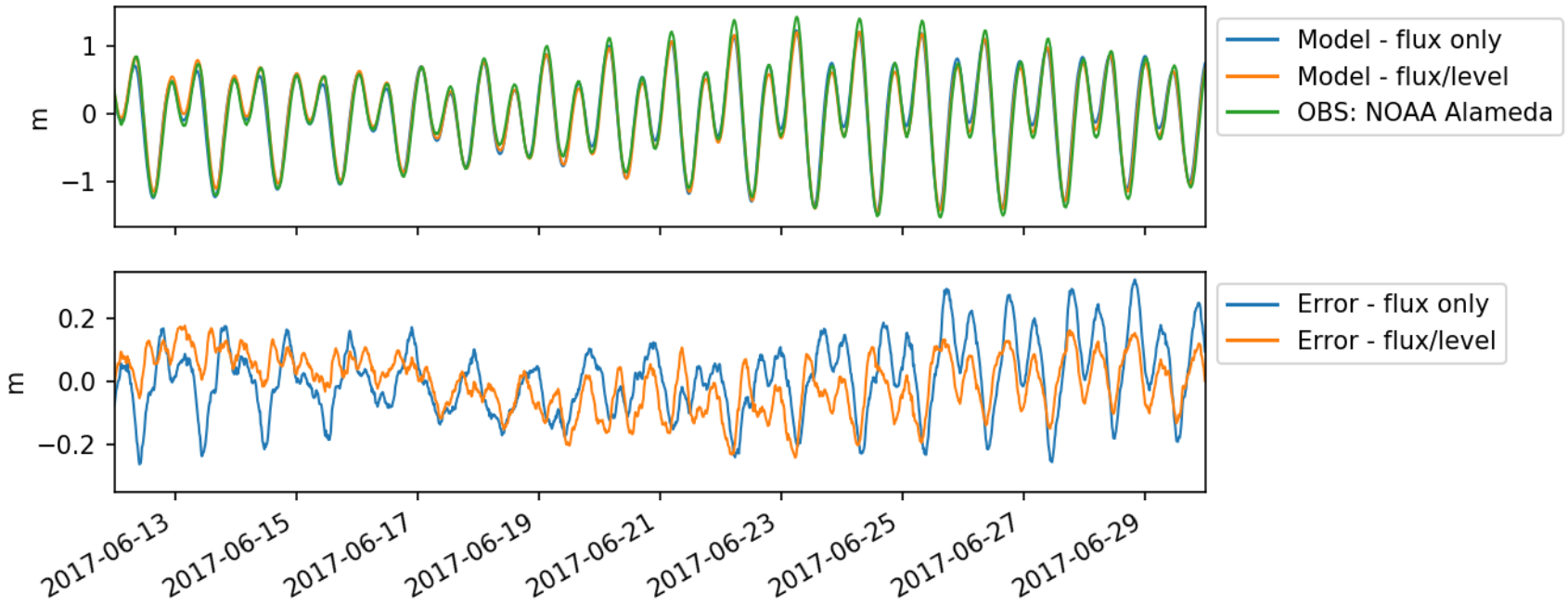
Boundary Fluxes

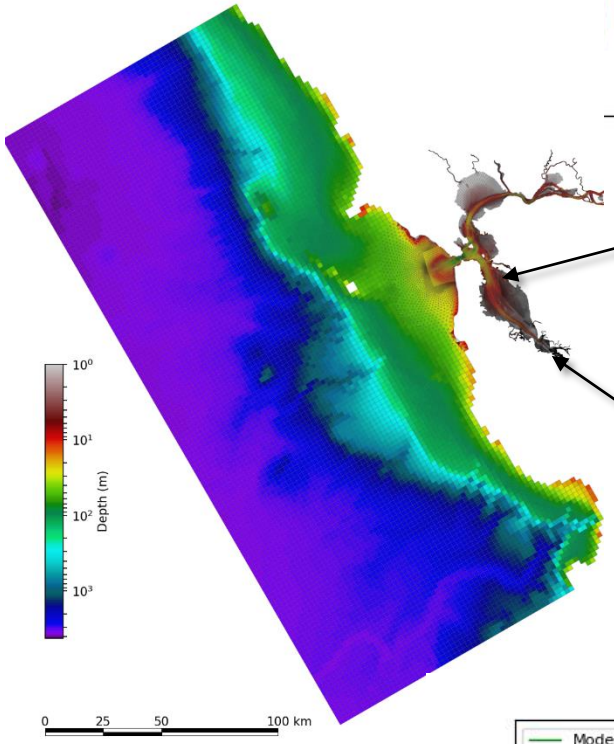
Typical SF Bay models force free surface elevation, constant salinity/temperature.

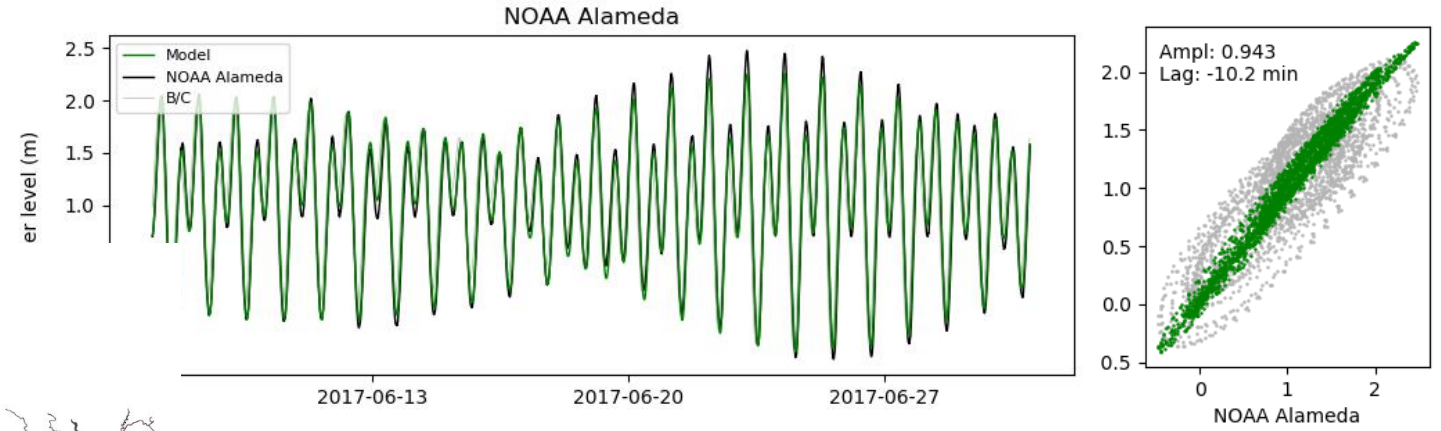
Deep (4000m) boundary, need coastal circulation and gradients.

Deep, baroclinic boundary unstable when forcing free surface elevation.

Follow Rayson approach:
Force velocity in deep areas
Force water level in shallow areas

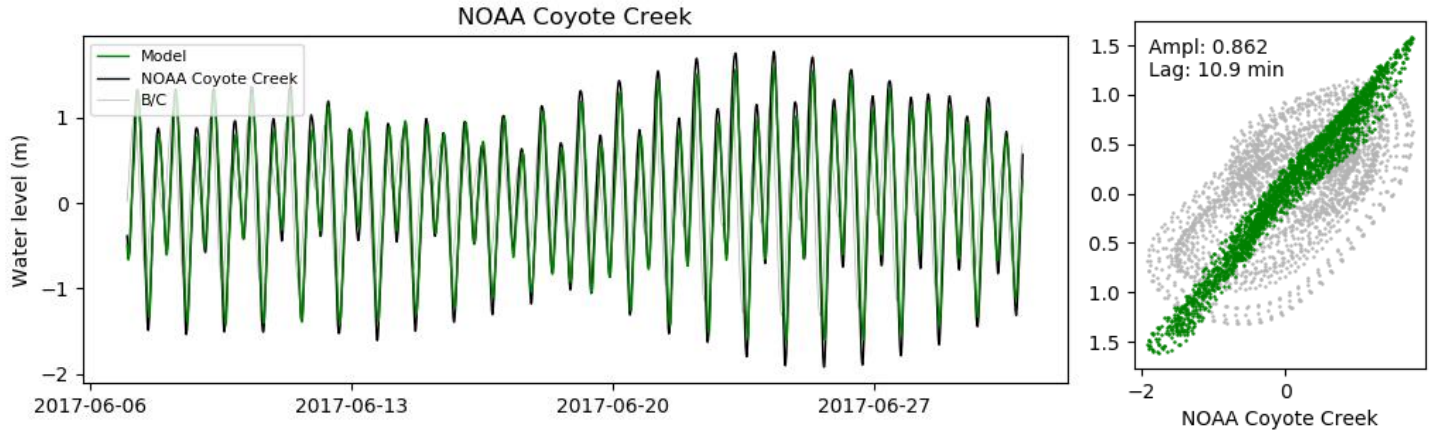




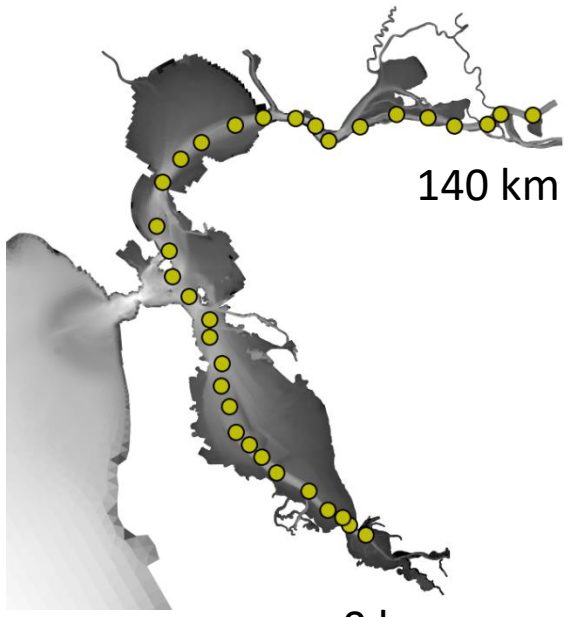


Validation: Tidal Propagation

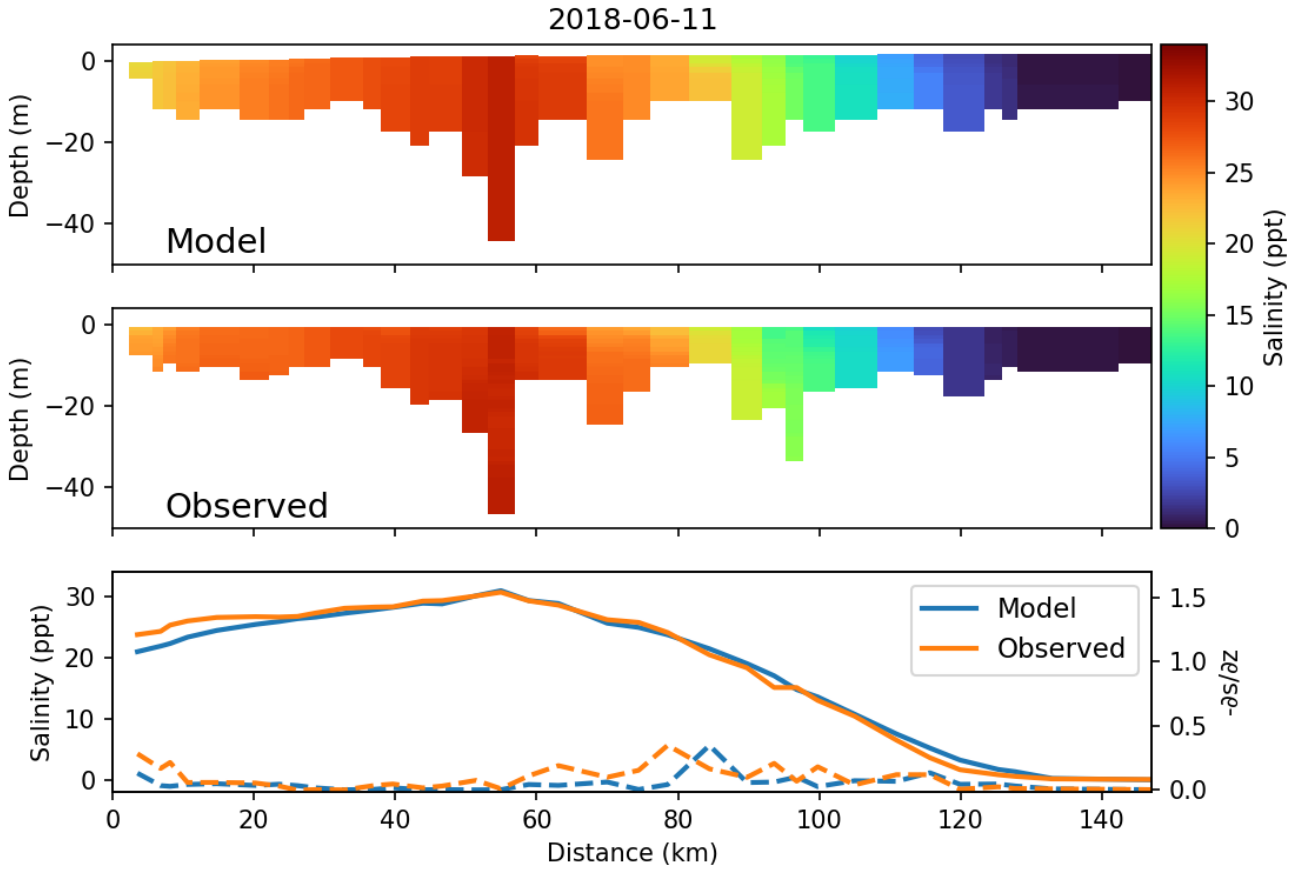
Good tidal phasing and reasonable amplitude.



Validation: Salt Intrusion

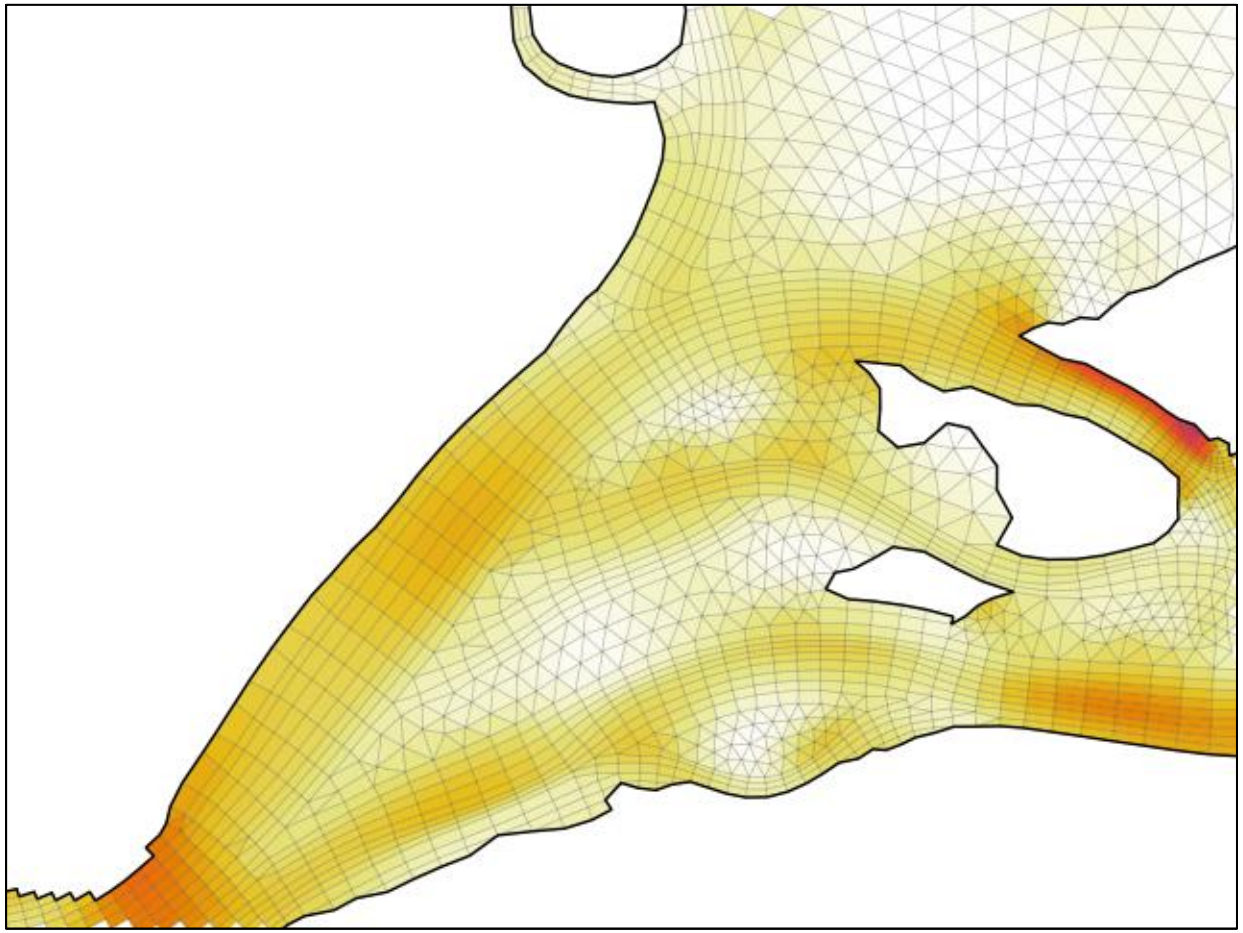


Monthly Cruises

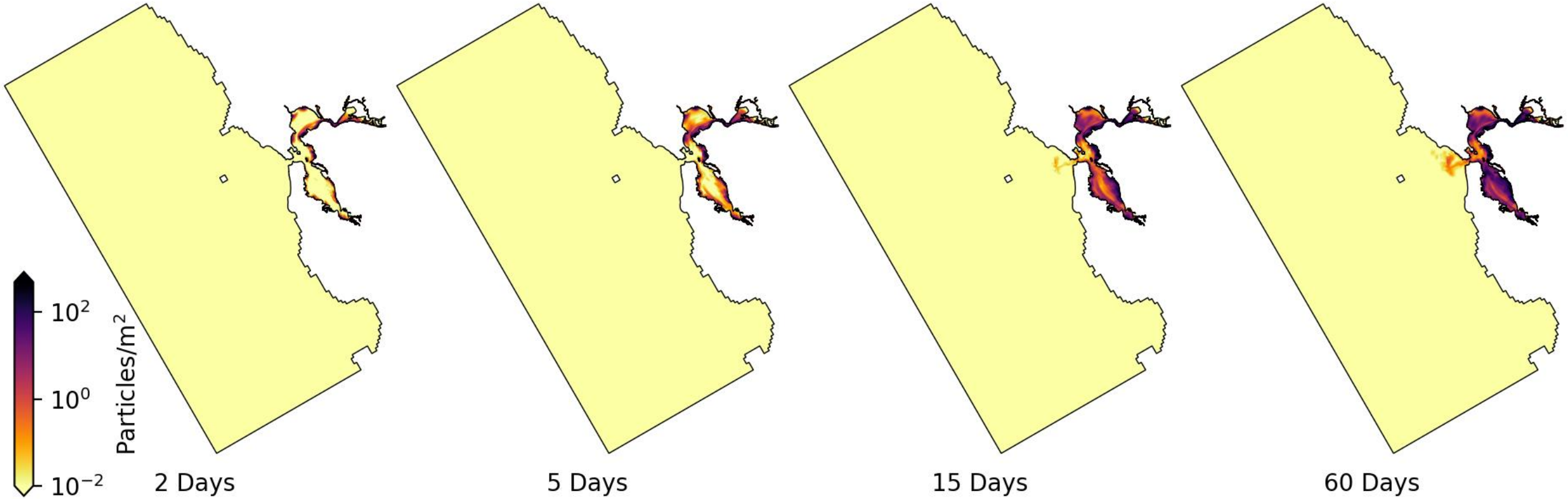


Particles and Concentration

1. Discrete particle locations
2. Map to cell, normalize by area
3. Smooth with minimal diffusion
4. or a lot of diffusion



Distribution by Max Age – Bed



Near-bed concentration Wet season 15-day average