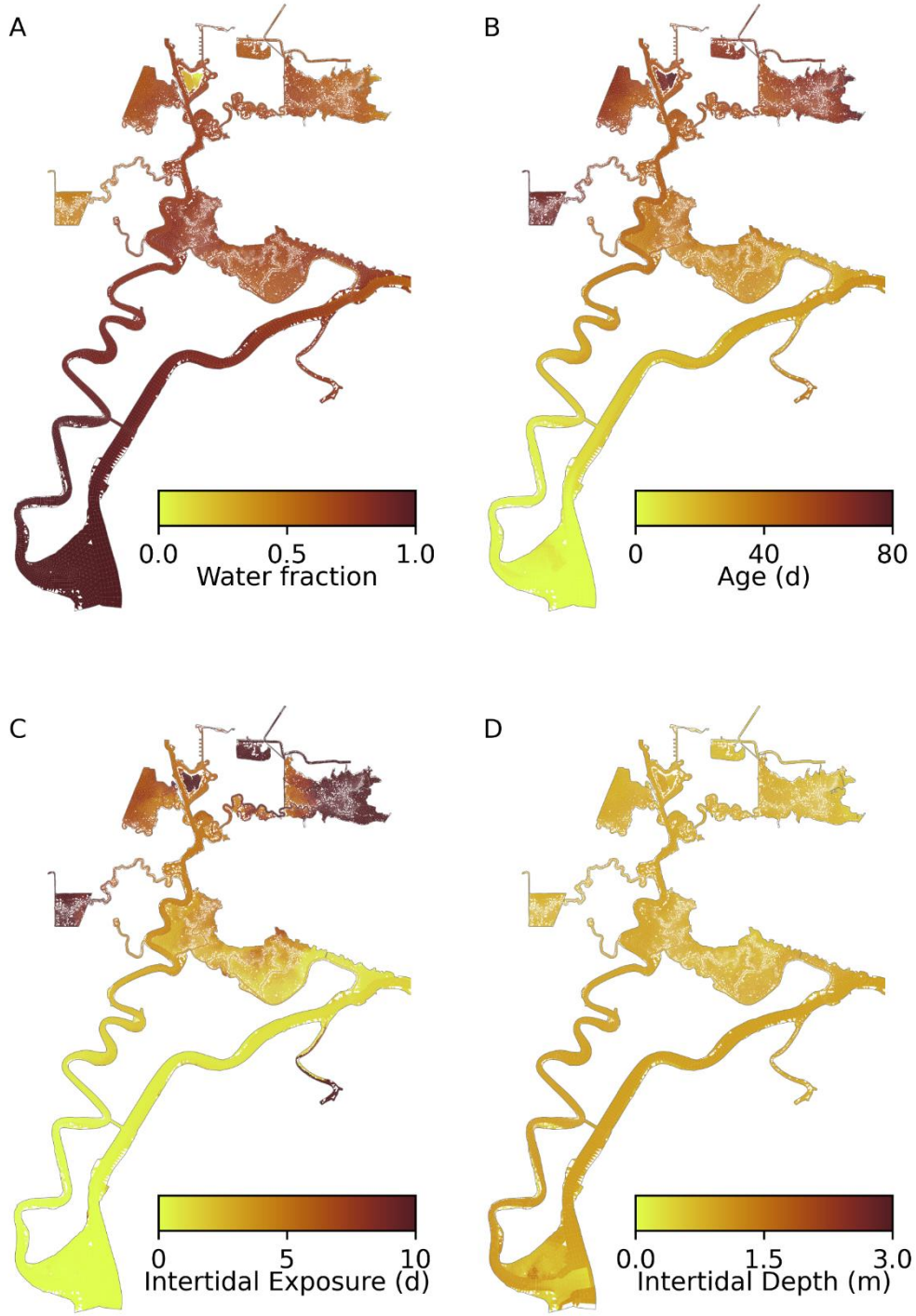
RMA RESOURCE MANAGEMENT ASSOCIATES
WATER RESOURCES ENGINEERING
A GEI Consultants, Inc. Company

Tracer-Based Phytoplankton Modeling

Hugo B. Fischer Award Acceptance Presentation

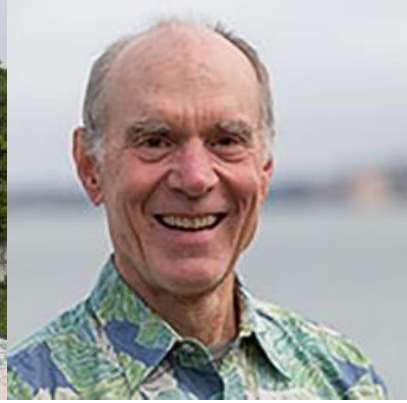
Edward Gross

September 23, 2024



Thank You Mentors!





- Jeffrey Koseff, Stephen Monismith
- Ralph Cheng, Jon Burau
- Vincenzo Casulli, Guus Stelling
- Wim Kimmerer, John DeGeorge, Richard Rachiele

Thank You RMA Team and Other Colleagues!

- Rusty Holleman – Modeling guidance and python scripts
- Richard Rachiele, Stacie Grinbergs – Modeling approach and inputs
- Steve Andrews – UnTRIM interface and application
- Benjamin Saenz – Python scripts and model inputs
- John DeGeorge – Business development and project management
- Scott Burdick – Hydrodynamic grid and model setup
- Michael MacWilliams, David Ralston, Gerard Ketefian, Nick Nidzieko

Questions for Suisun Marsh Phytoplankton Modeling

- Which regions of Suisun Marsh are most productive?
- What are the mortality rates?
  - Clam grazing
  - Zooplankton grazing or other mortality

water

MDPI

Article

Using Age Tracers to Estimate Ecological Rates in a Phytoplankton Model

Edward Gross [1,2,*], Rusty Holleman [3], Wim Kimmerer [4], Sophie Munger [3], Scott Burdick [1] and John Durand [3,5]

Ecological Modeling Approaches

Option 1: Box model

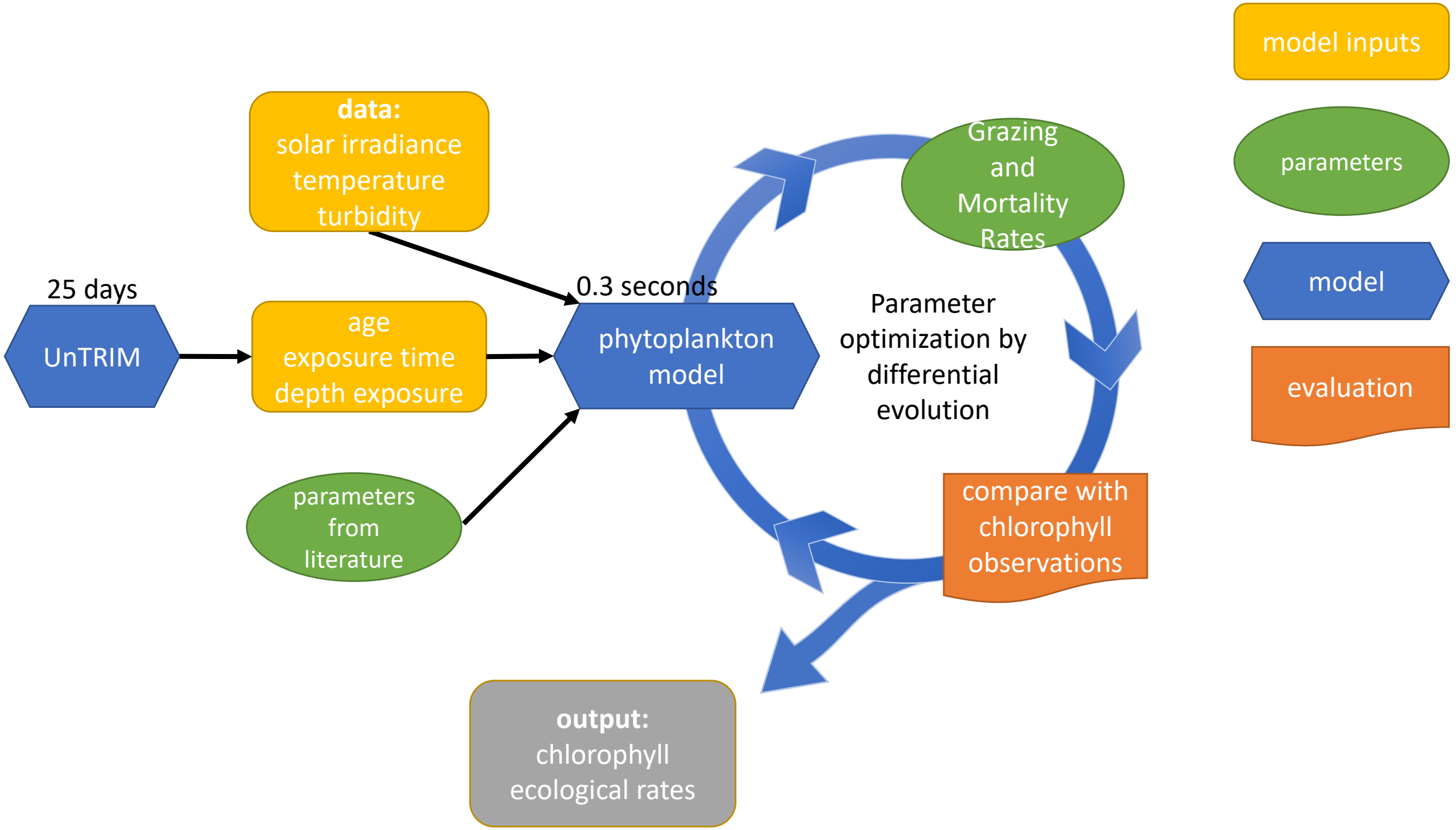
- Fast, simple
- Ignore or drastically simplify transport

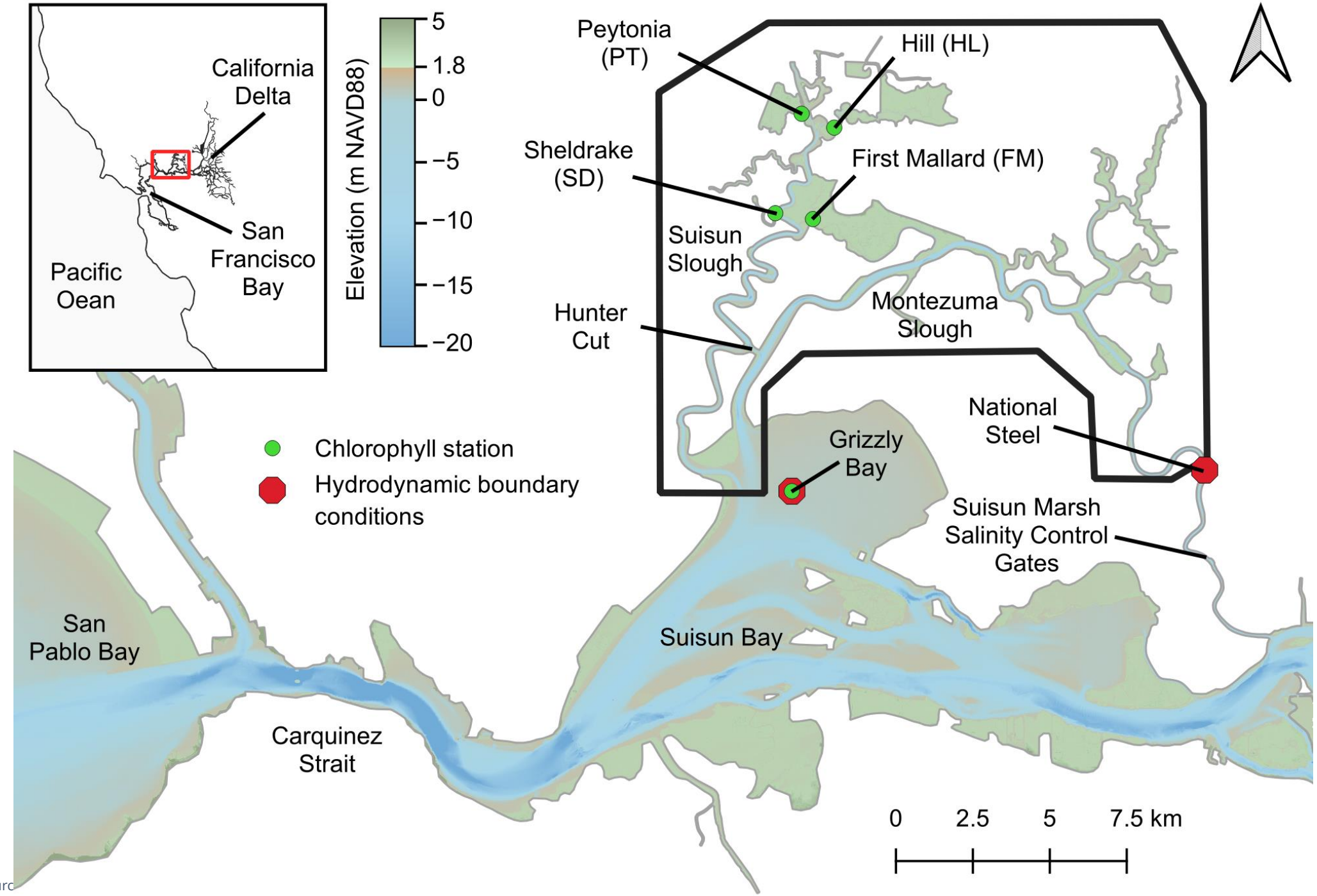
Option 2: Coupled hydrodynamics and ecology

- Transport affects transformation
- Slow

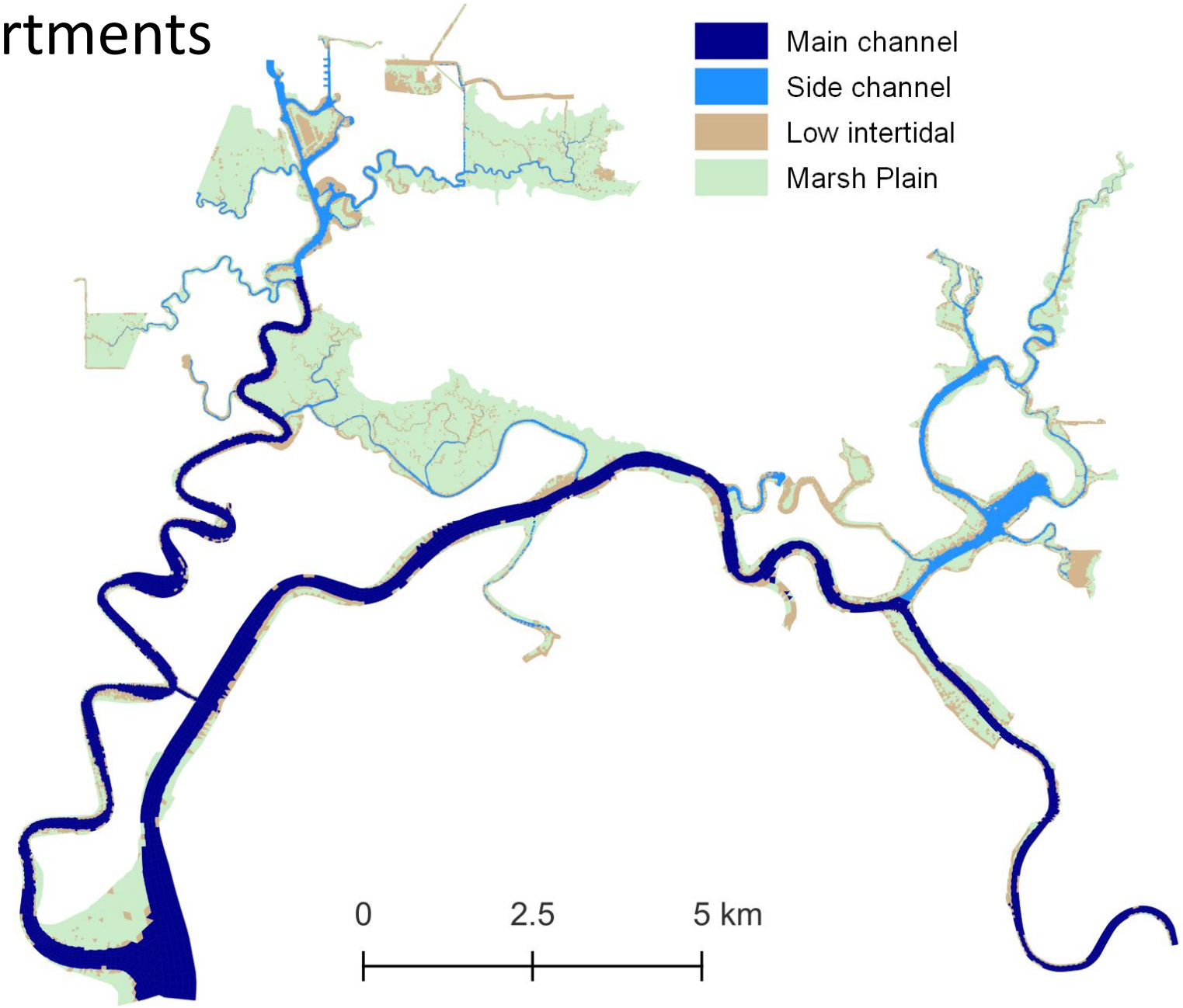
Option 3: Lagrangian model utilizing water age tracers

A box model where “the box is moved around by the hydrodynamics.”

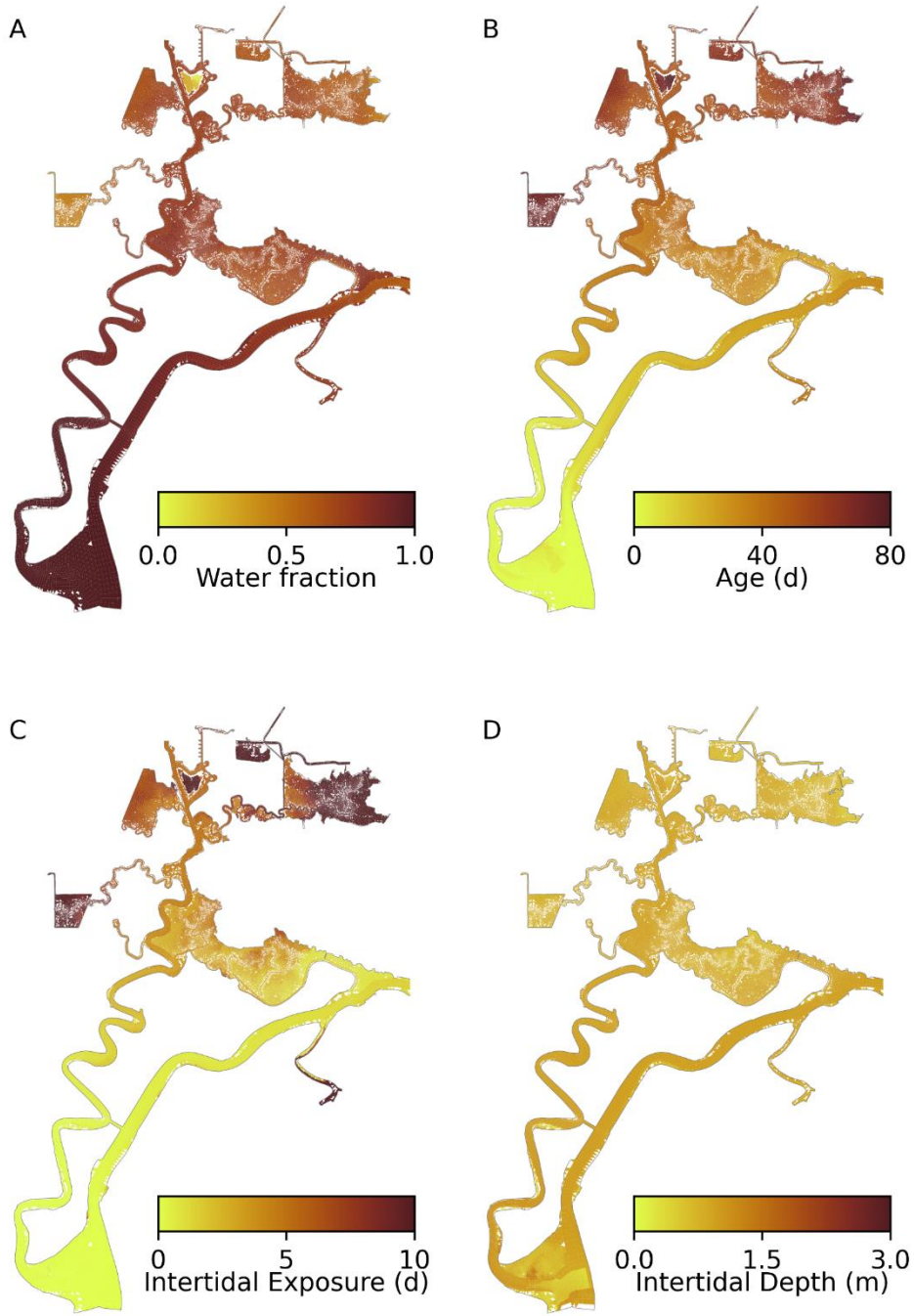

model inputs
parameters
model
evaluation
data:
solar irradiance
temperature
turbidity
25 days
UnTRIM
age
exposure time
depth exposure
0.3 seconds
phytoplankton
model
parameters
from
literature
Grazing
and
Mortality
Rates
Parameter
optimization by
differential
evolution
compare with
chlorophyll
observations
output:
chlorophyll
ecological rates


California Delta
San Francisco Bay
Pacific Oean
Elevation (m NAVD88)
5
1.8
0
−5
−10
−15
−20
Peytonia (PT)
Hill (HL)
Sheldrake (SD)
First Mallard (FM)
Suisun Slough
Montezuma Slough
Hunter Cut
National Steel
Grizzly Bay
Suisun Marsh Salinity Control Gates
Chlorophyll station
Hydrodynamic boundary conditions
San Pablo Bay
Carquinez Strait
Suisun Bay
0
2.5
5
7.5 km

Spatial Compartments



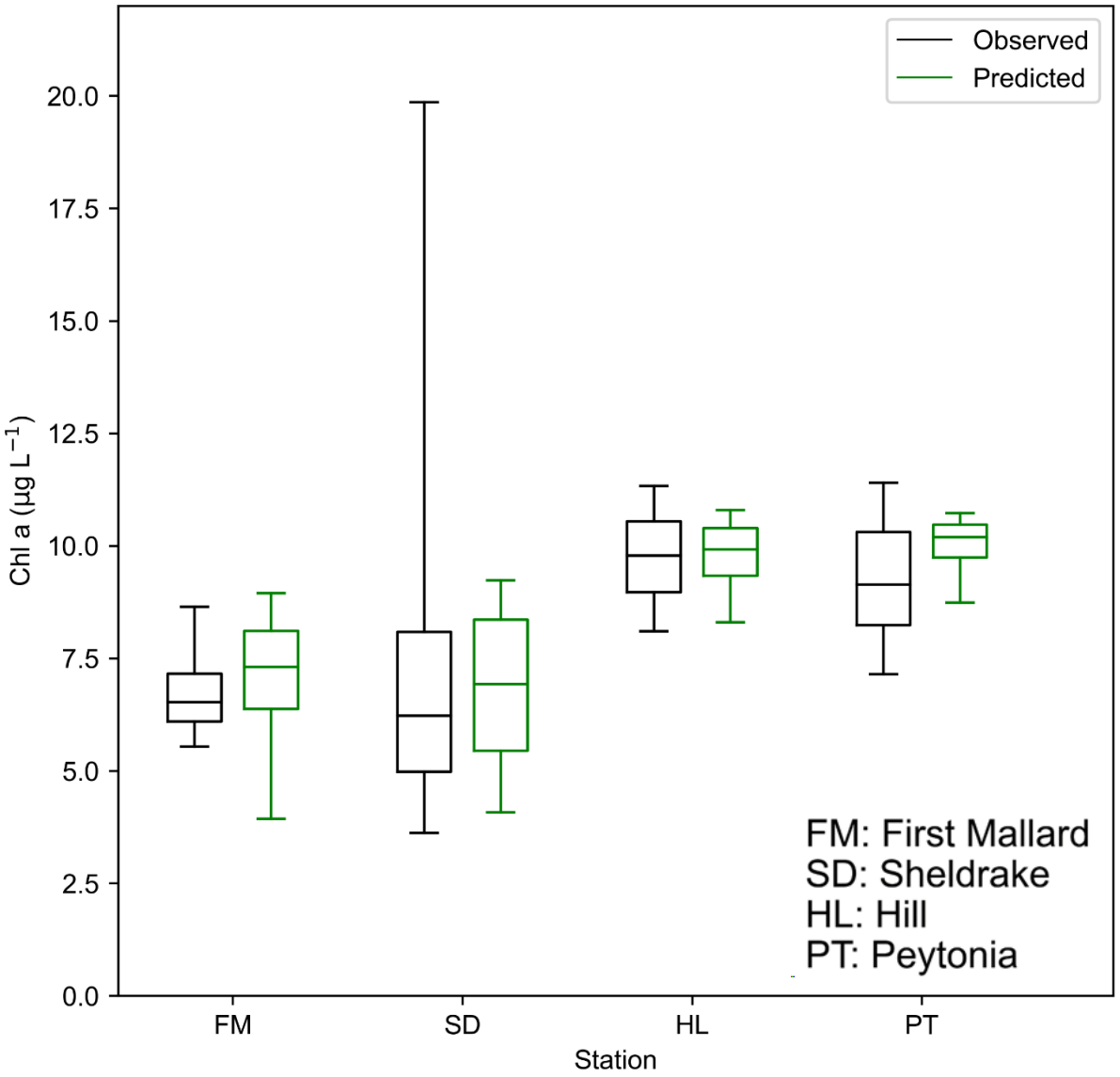
Example Snapshots of Predicted Tracer Distributions

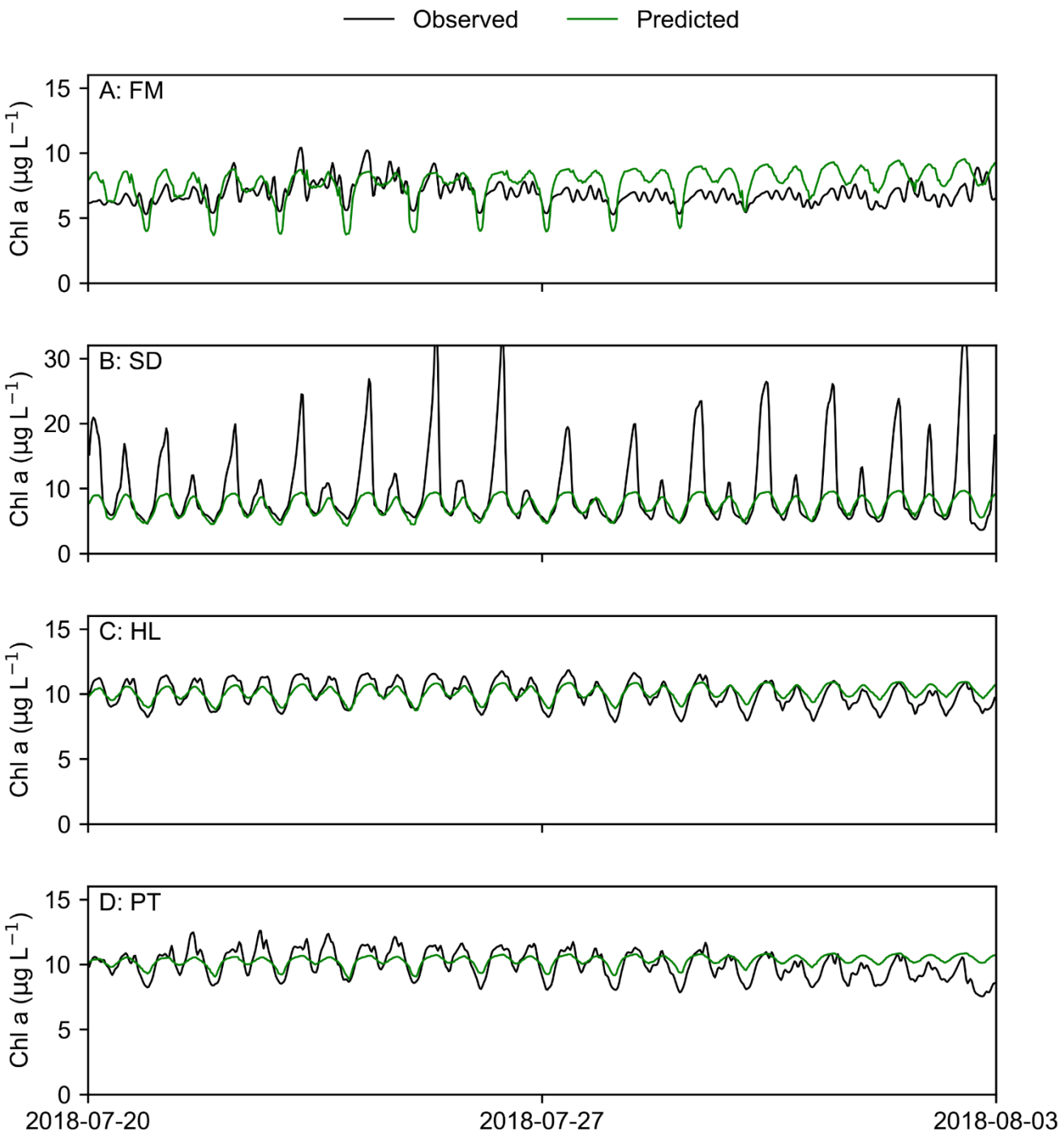


Water Age Tracer-Based Phytoplankton Model

- Light limited production equations from Cloern (2007)
- Losses (*unknown parameters in green*)
  - $\mu_{loss} = \mathrm{PM} + \mathrm{ZG} + \frac{\mathrm{CG}}{\mathrm{H}}$
    - PM is phytoplankton mortality rate (d^{-1})
    - ZG is microzooplankton grazing rate (d^{-1})
      - $\mathrm{ZG} = \max(0, -0.3 + 0.93 * \mu_{growth})$ (Kimmerer and Thompson 2014)
    - CG is clam grazing rate ($m\ d^{-1}$)
- **Analytical** solution for chlorophyll concentration (Wang et al. 2019)
  - $\mathrm{P(a)} = \frac{\mathrm{P_{in}(t-a)e^{\overline{\mu_{net}}\,a}}}{1+\mathrm{k_p P_{in}(t-a)(1-e^{\overline{\mu_{net}}\,a})}}$

Calibration

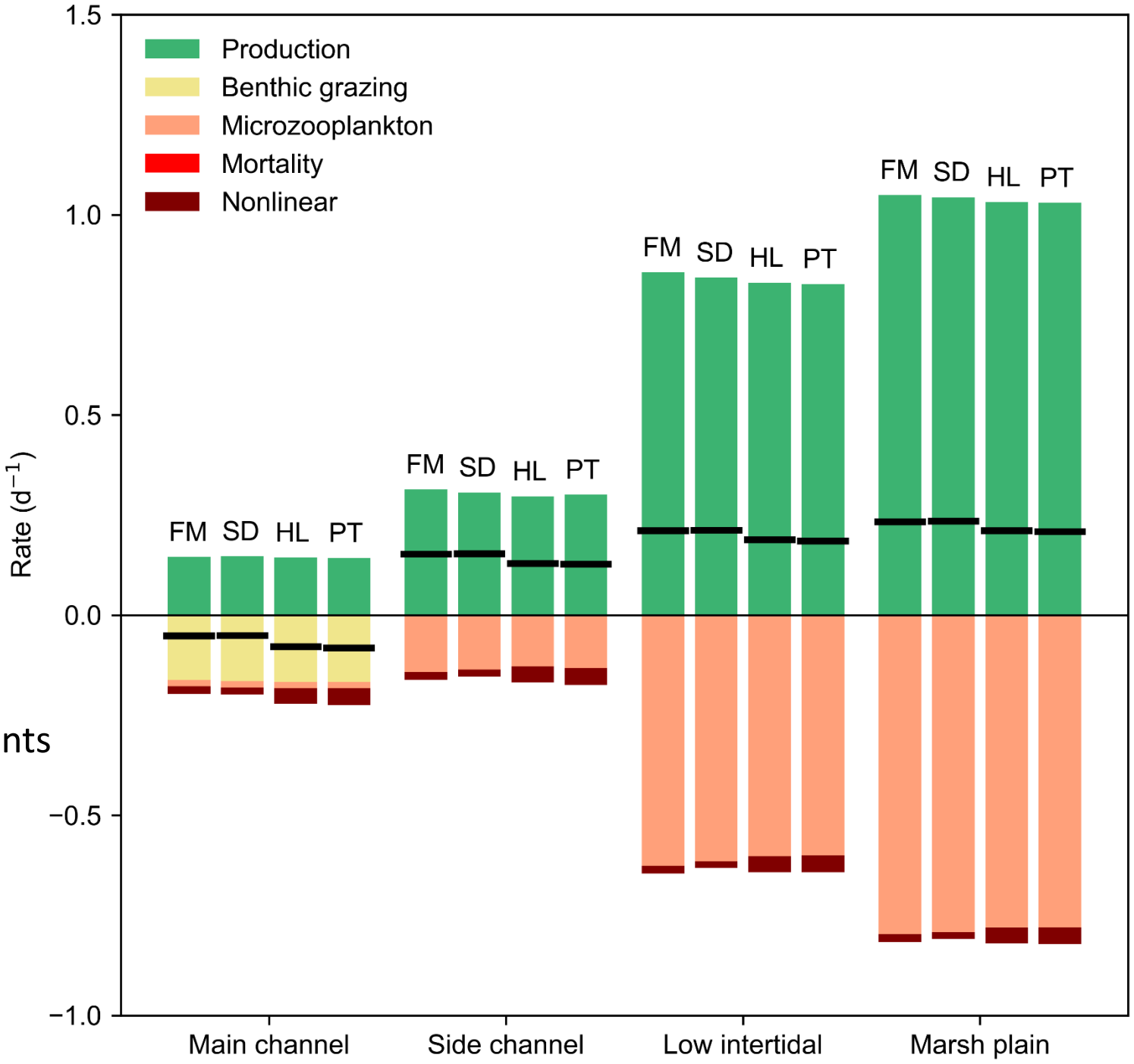




Best-Fit Parameters

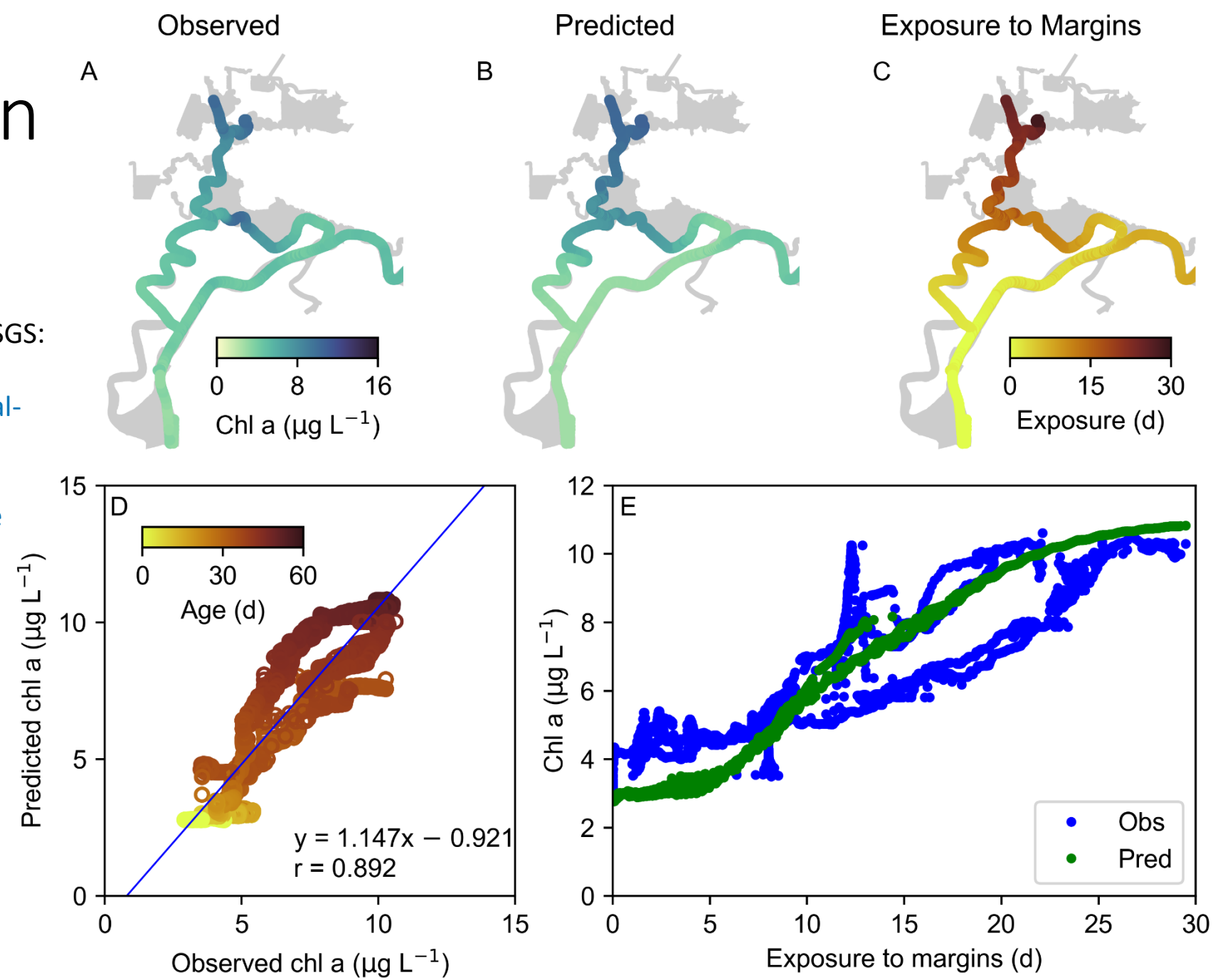
Parameter	Best Fit Value
Main channel grazing	1.13 m d^{-1}
Side channel grazing	0 m d^{-1}
Nonlinear feedback	-0.091 L μg^{-1}
Mortality	0.0 d^{-1}

- Net loss in main channel
- Net production in other spatial compartments
- Only non-zero estimated grazing rate is in main channel



Validation

High-speed mapping data from USGS: Bergamaschi et al. 2021 https://www.usgs.gov/data/spatial-assessmentnutrients-and-water-quality-constituents-suisun-marsh-salinity-control-gate



Conclusions

- The strength of this type modeling approach is to quickly:
  - Test model formulations
  - Fit unknown rates or other parameters to data
  - Gain conceptual understanding
- Derived rates can be used in a more complex ecological model
- Difficulties to applying at larger spatial and temporal scales
  - Spatial and temporal variability in parameters
  - Multiple sources of water

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