UNESCO Workshop
May 28, 2014

Estuarine Hydrodynamic and Water Quality Modeling

Detong Sun, Ph.D

Coastal Ecosystems Section, Applied Science Bureau

Outline of Presentation

- Background
- Objectives
- Integrated framework
- Hydrodynamic modeling
- WQ modeling efforts

  a. 3D model

  b. Box model
- Conclusions

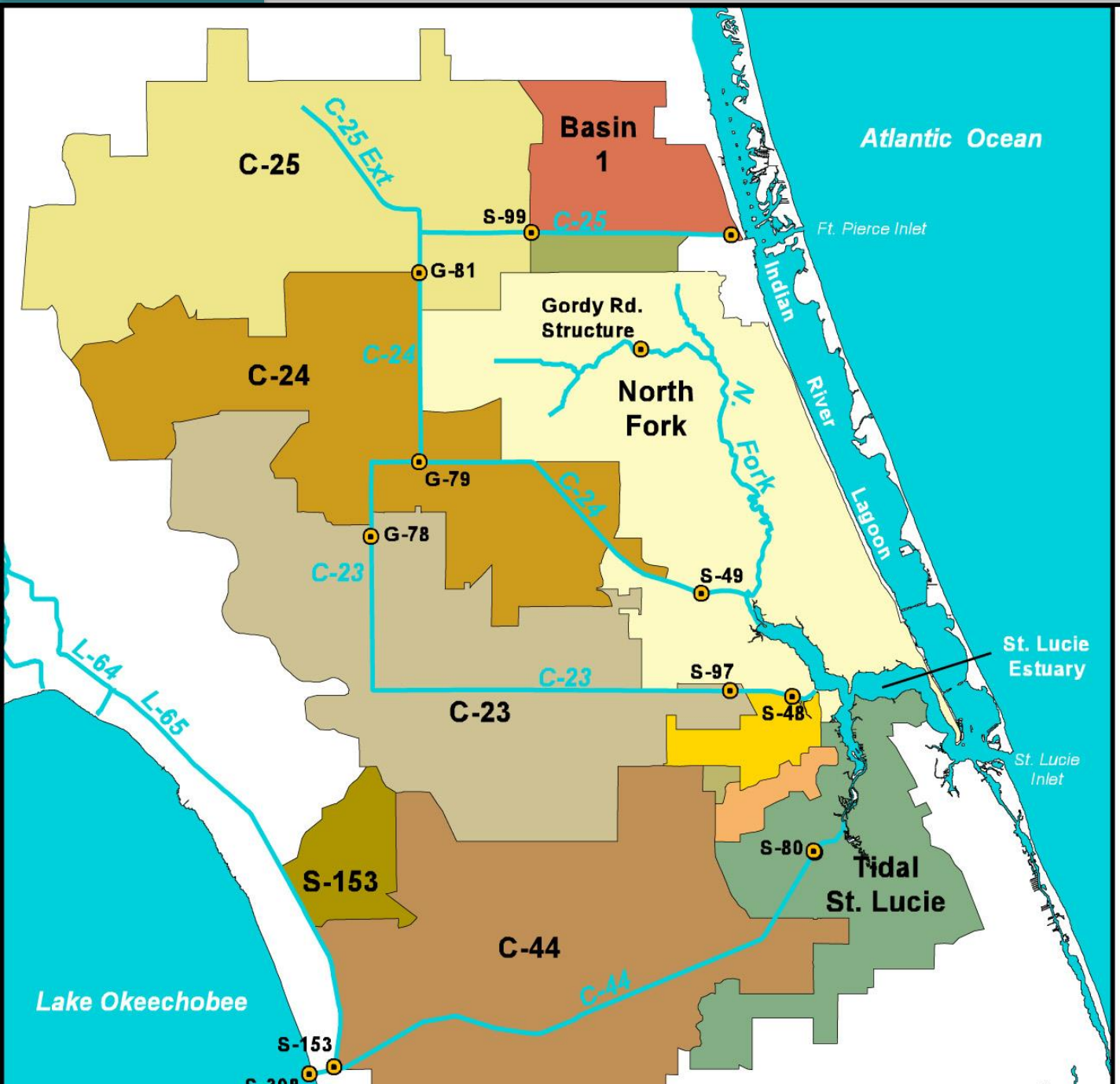
Background & Objectives

Application of hydrodynamic models:

- Operation support (salinity forecast)
- Minimum flow and levels (MFL)

Application of water quality moels

- Total maximum daily load (TMDL)
- Numeric nutrient criteria (NNC)



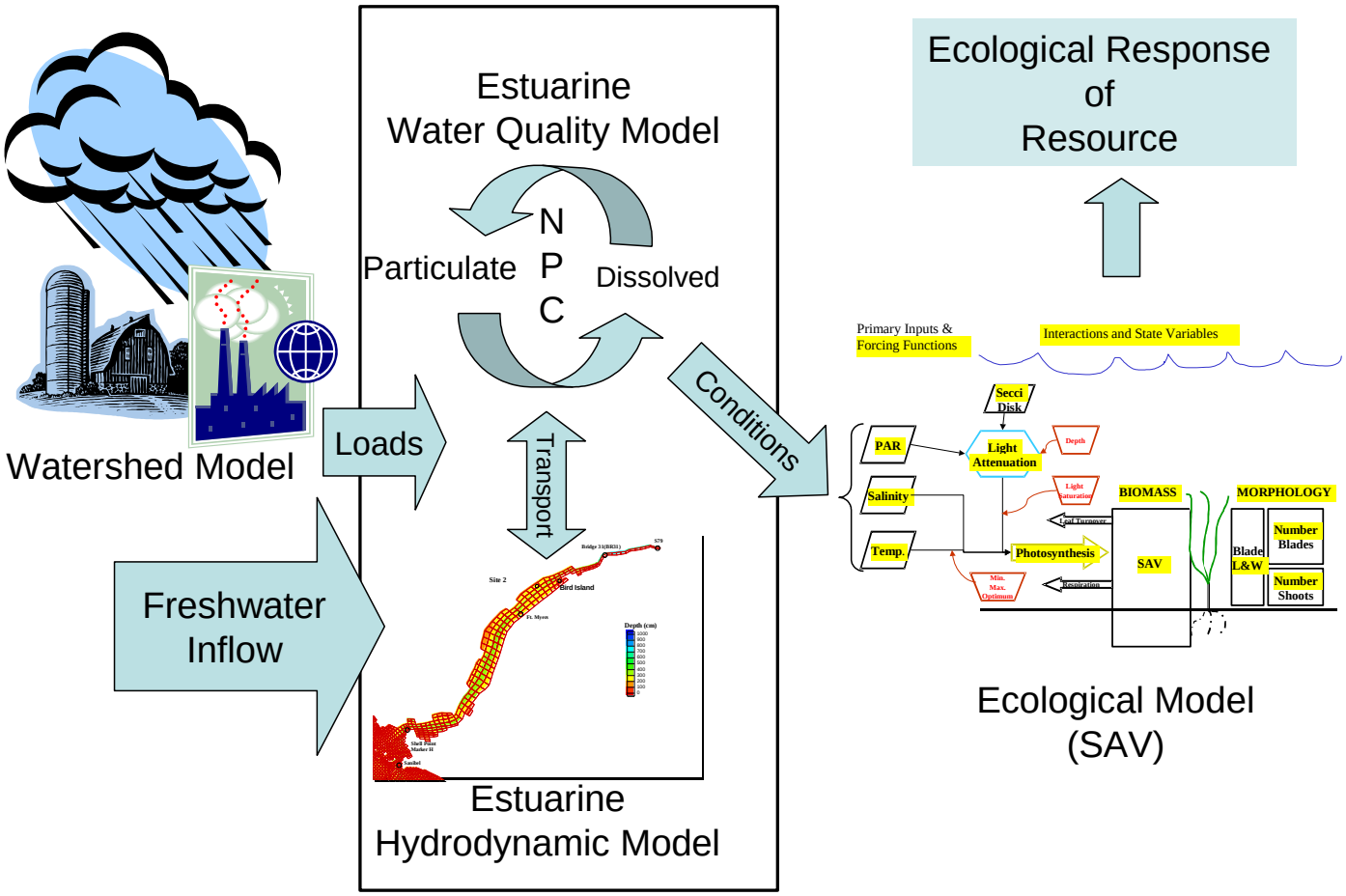
St. Lucie Estuary Watershed

Background & Objectives

- Construction of canal systems
- Opening of the Inlet
- Agriculture and urbanization
- Increased nutrient and sediment loading
- Degraded water quality

Integrated Modeling Frame Work

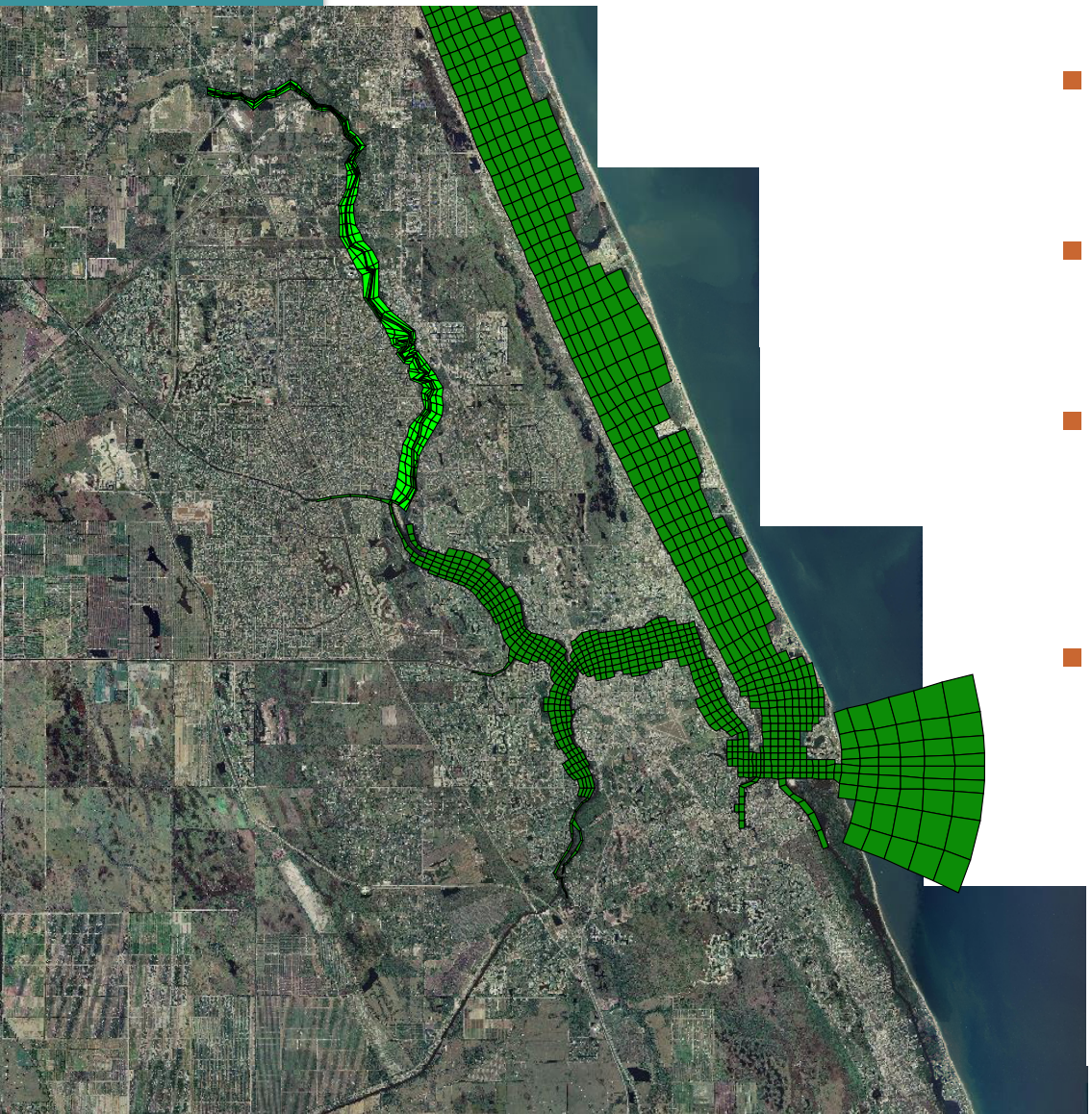
Figure . Integrated Modeling Framework



3D Model Components

- Hydrodynamic/salinity model: CH3D
- Water quality model: HEM-3D
- Sediment transport model: CH3D-SED
- Wave model: SMB
- External component :WaSh the Watershed model

3D Model Grid and Boundary Conditions



- Flow and concentrations at structures
- Flow and concentrations from Wash at ungaged area
- Tide and background concentrations at ocean boundaries
- Spatially interpolated concentrations from WQ monitoring stations as initial condition

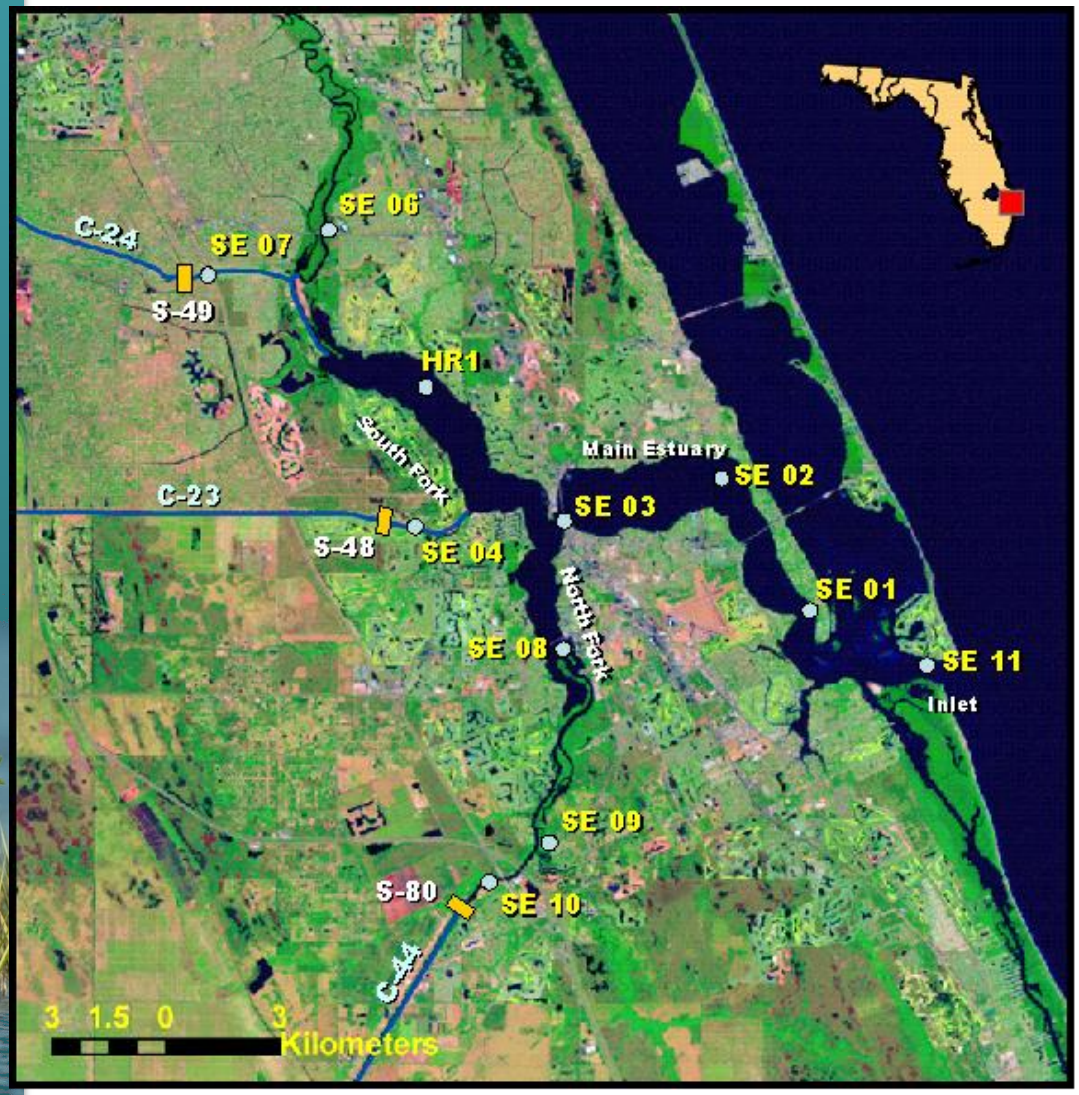
CH3D Hydrodynamic Model Features

- Non-orthogonal boundary fit grid
- Sigma grid in the vertical
- Semi-implicit scheme
- Originally developed by UF
- Applied to many South Florida Estuaries

HEM3D WQ Model Features

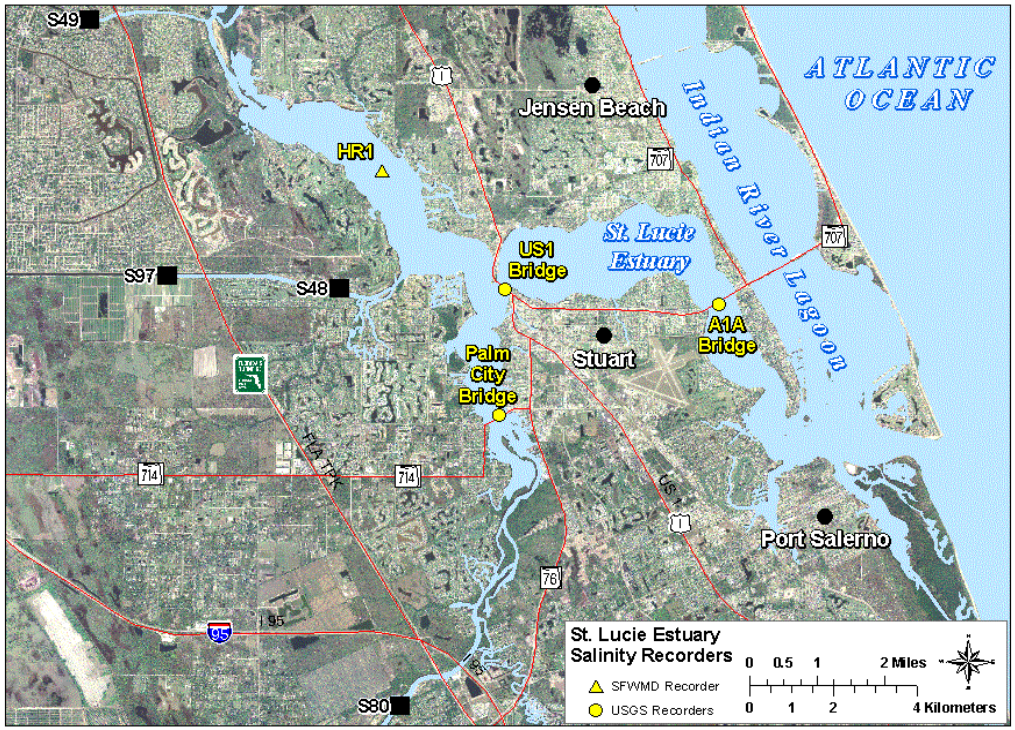
- Very similar to CE-QUAL-ICM (Chesapeake Bay Model)
- 21 state variables including multiple classes of algae, organic carbon, nitrogen and phosphorus
- Optional sediment diagensis model (27 state variables)

Water Quality Monitoring Stations

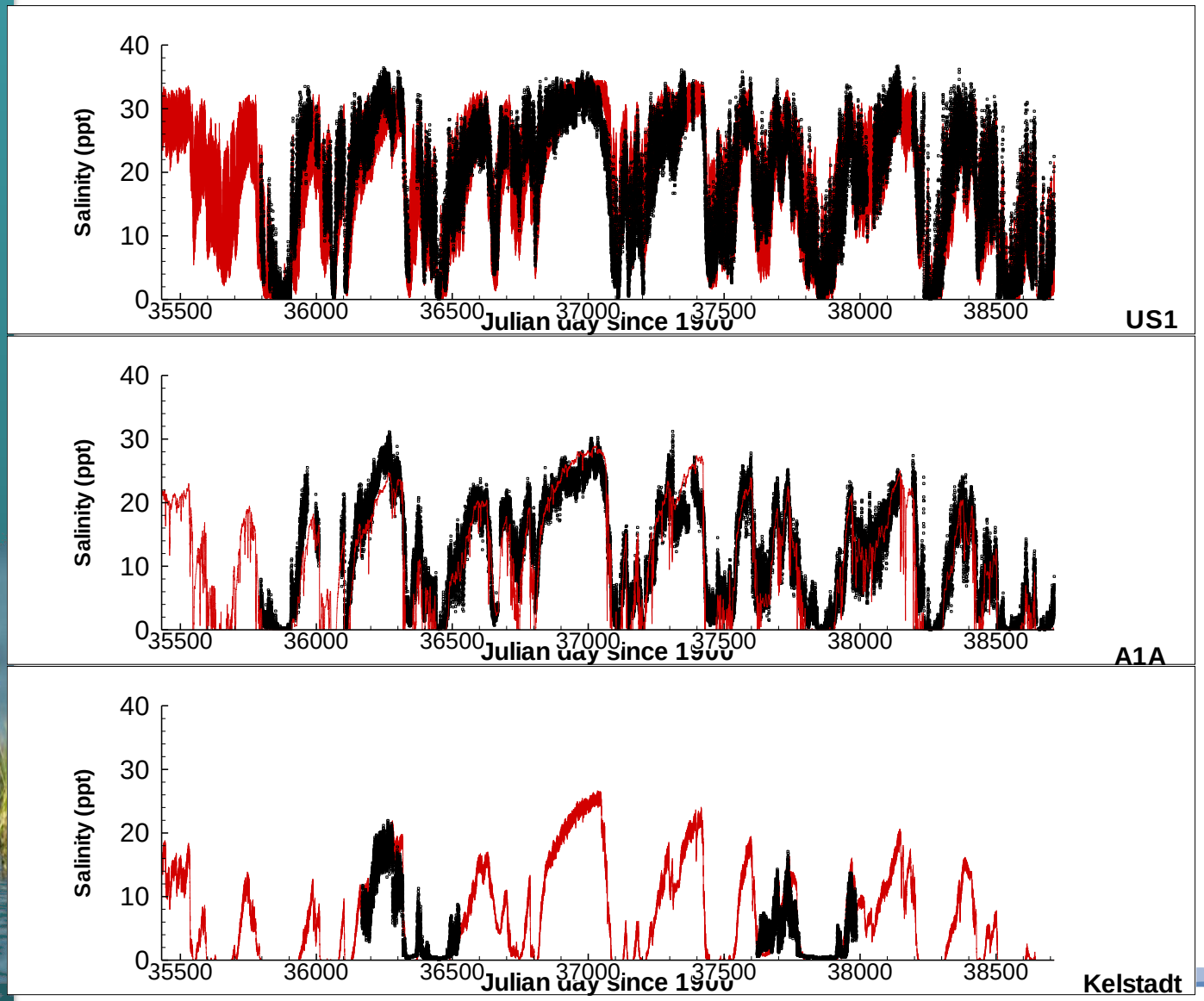


Hydrodynamic/Salinity Model

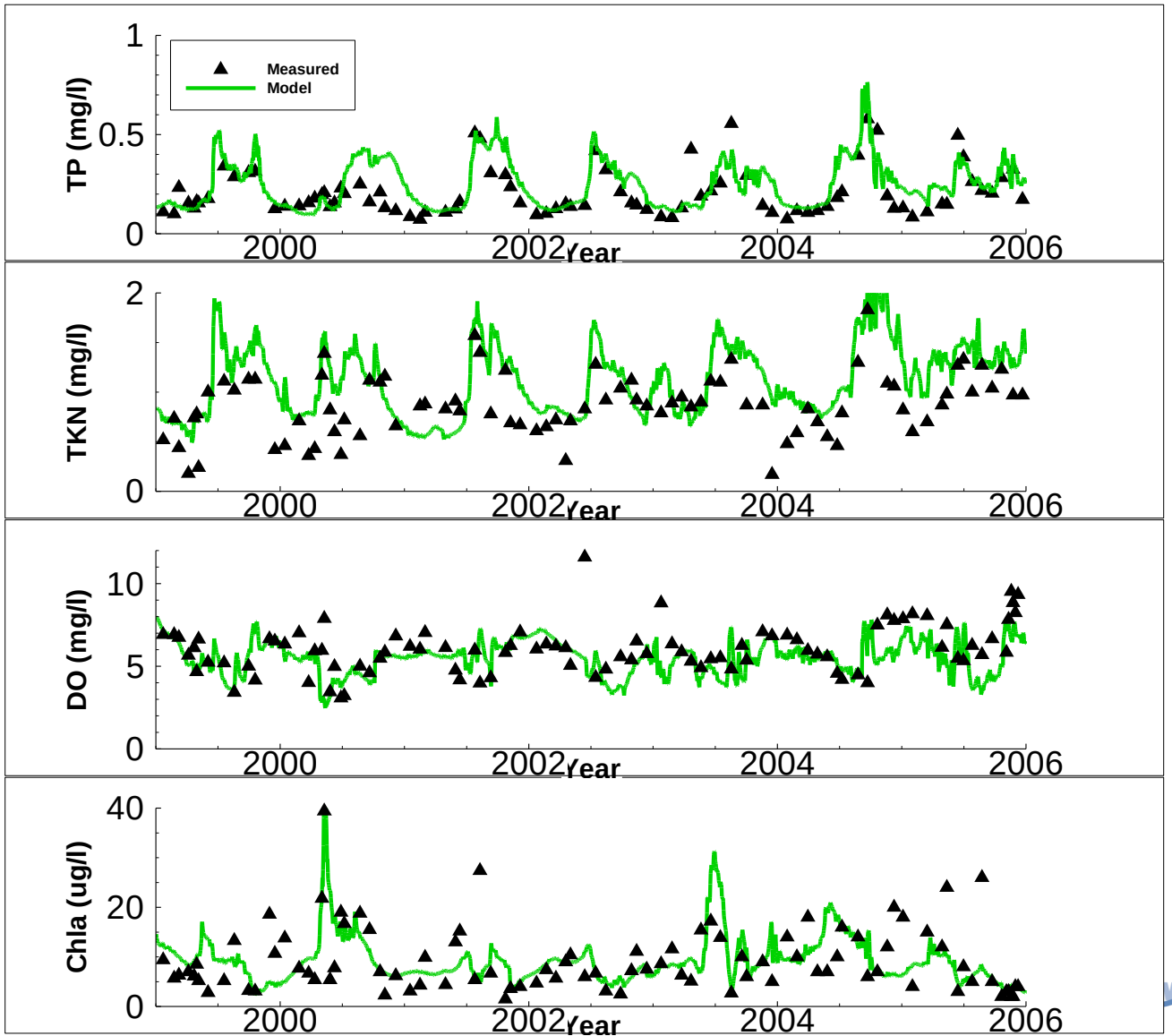
- Well calibrated with long-term monitoring data for the period of 1997 to 2005
- Long-term simulation from 1965 to 2005
- Application to North Fork Water Reservation



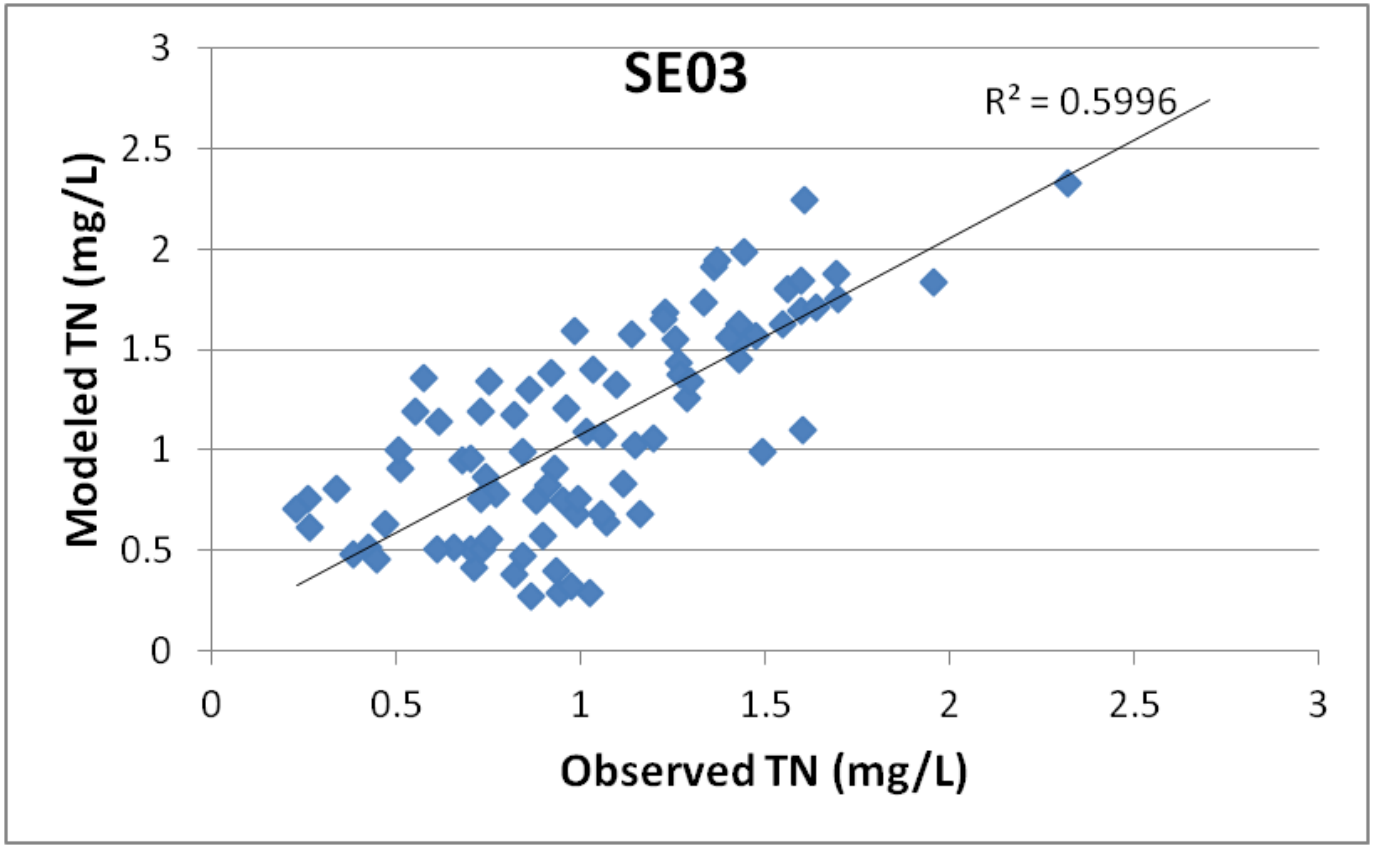
Salinity Model Results (1997-2005)



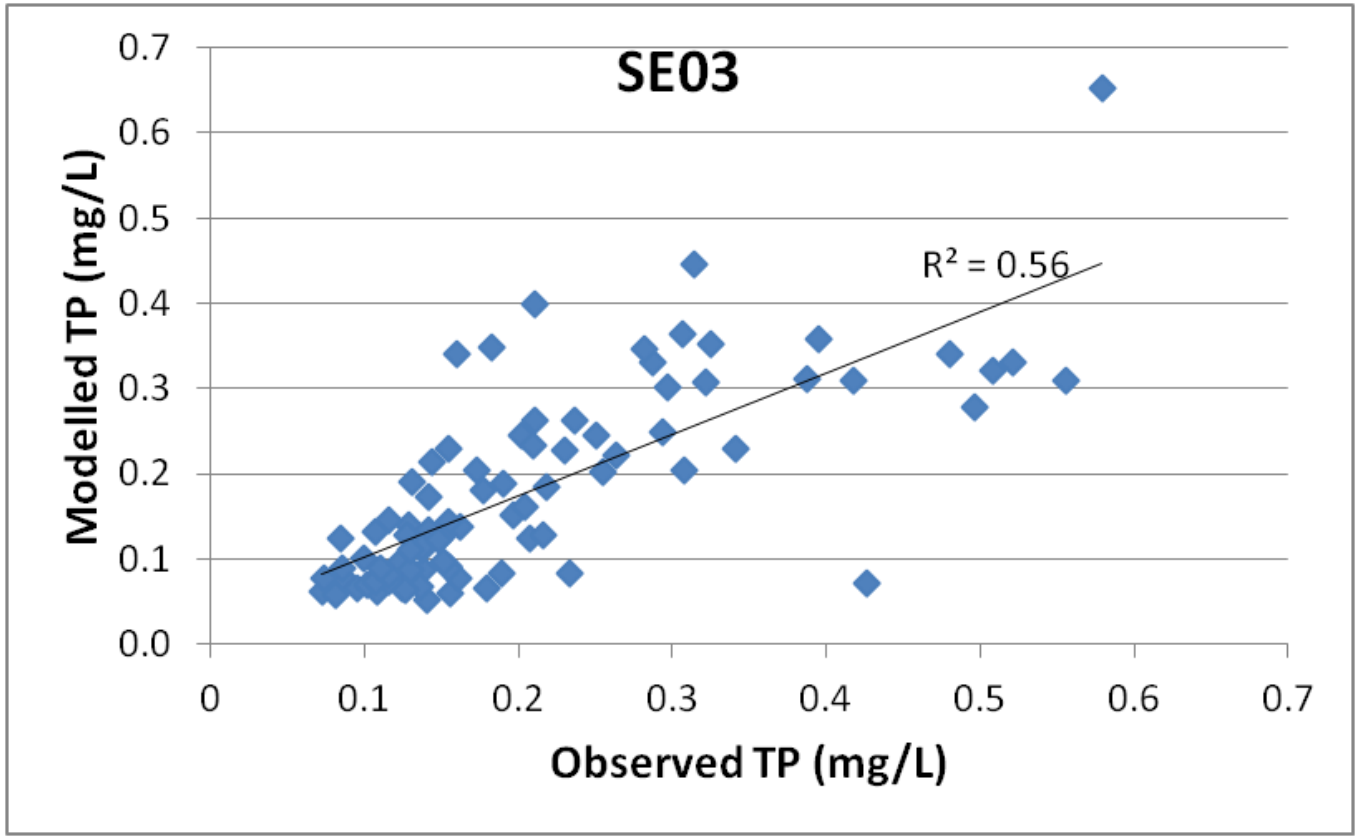
3D WQ Model Results (SE03)



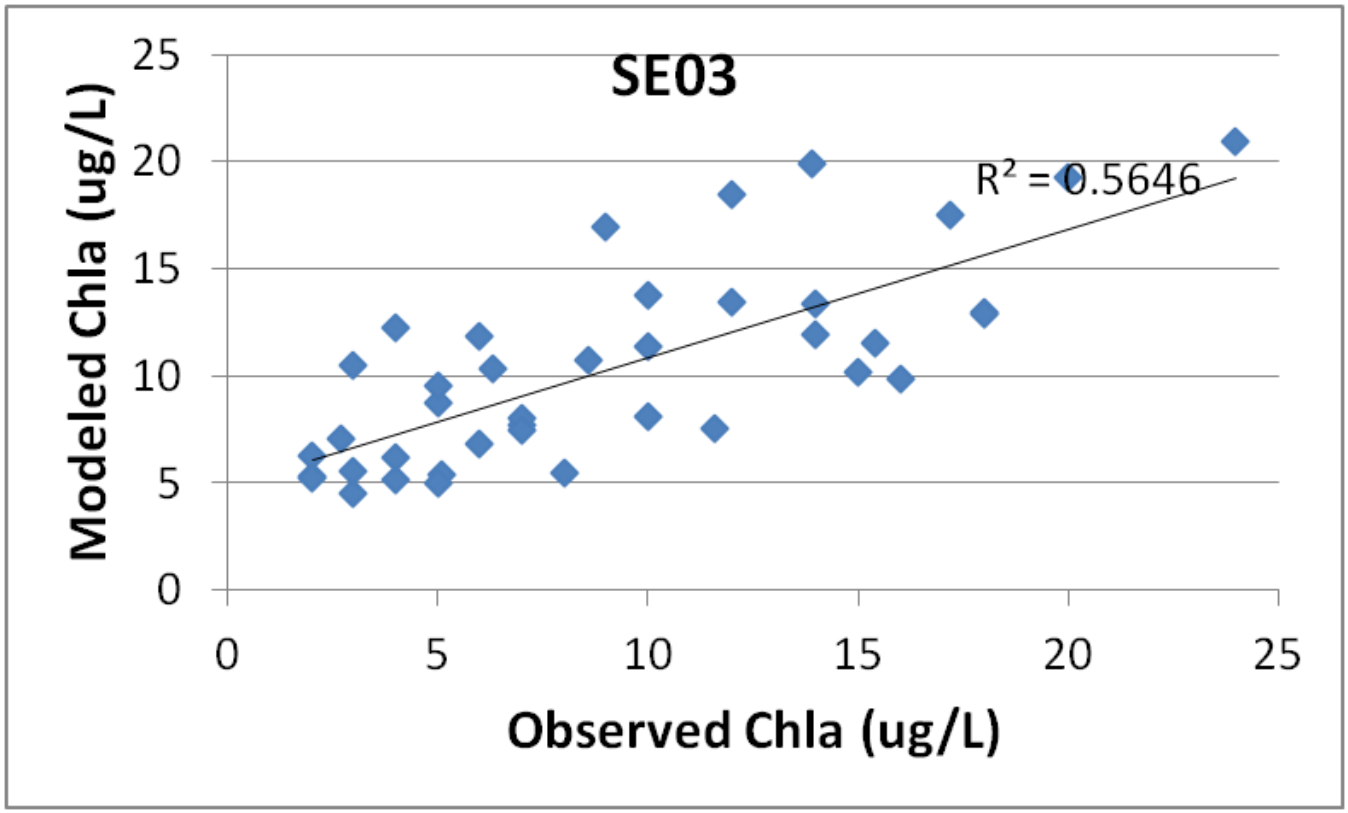
3D Model, TN (SE03)



3D Model, TP (SE03)



3D Model, Algae (SE03)



Box Model For Nutrients

The Conceptual Box Model:

- First order decay or removal
- Well mixed
- Internal or other sources included

$$V\frac{dN}{dt} = Q_r N_r + Q_s N_s + L_I - (Q_r + Q_s)N - VkN$$

Box Model For Algae

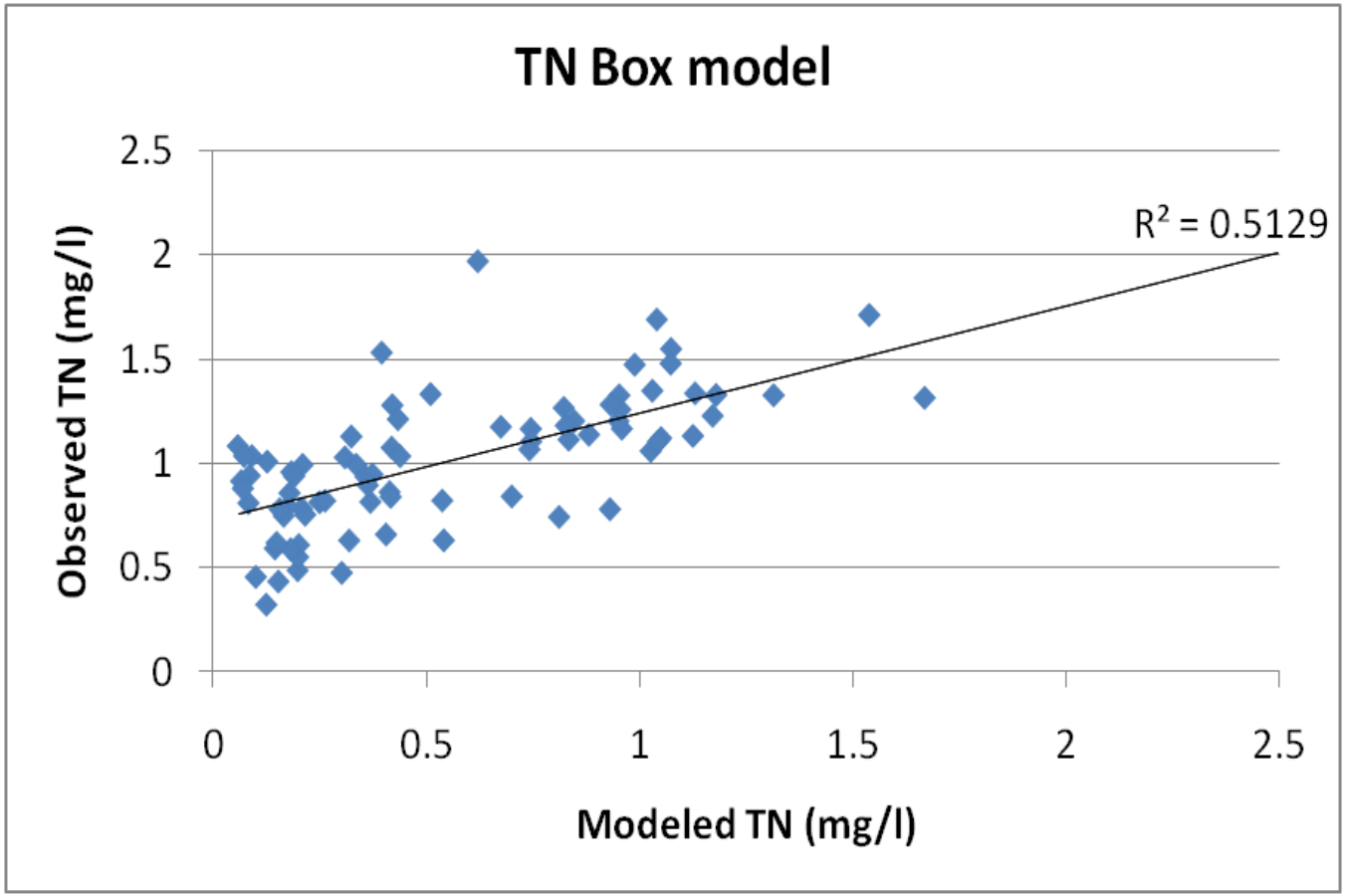
$$V\frac{dC}{dt} = Q_r C_r + Q_s C_s - (Q_r + Q_s)C$$

$$-VkC$$

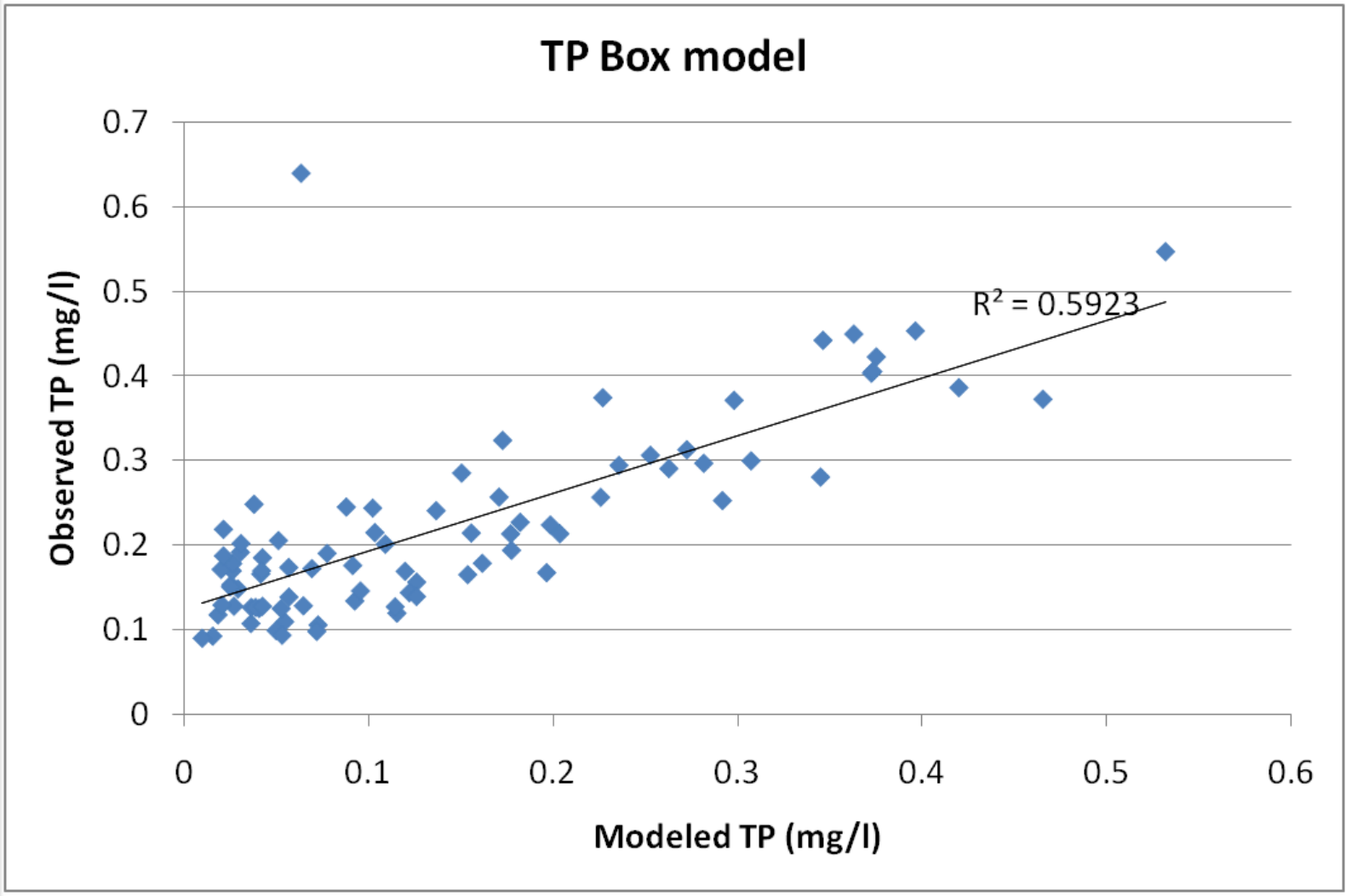
$$k = (R + P - G)$$

$$G = \frac{1}{4.61}\alpha Z_p I_0$$

Box Model, TN


TN Box model
Observed TN (mg/l)
Modeled TN (mg/l)
R² = 0.5129
0
0.5
1
1.5
2
2.5

Box Model, TP


TP Box model
Observed TP (mg/l)
Modeled TP (mg/l)
R² = 0.5923
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

Conclusions

- Hydrodynamic models are reliable tools for predicting salinity
- WQ model needs to be scientifically solid and practically useful
- Model should be simplified as much as possible but has to retain the essential dynamics and spatial and temporal resolutions

A Box Water Quality Model for the St. Lucie Estuary and the Southern Indian River Lagoon

Detong Sun, Ph.D and Yongshan Wan, Ph.D, P.E.

Coastal Ecosystems Section, Applied Science Bureau