Simulating the Tug of War Between Transport and Nutrient Uptake in Low Flow Treatment Wetlands Demonstrates the Need to Model Biogeochemistry

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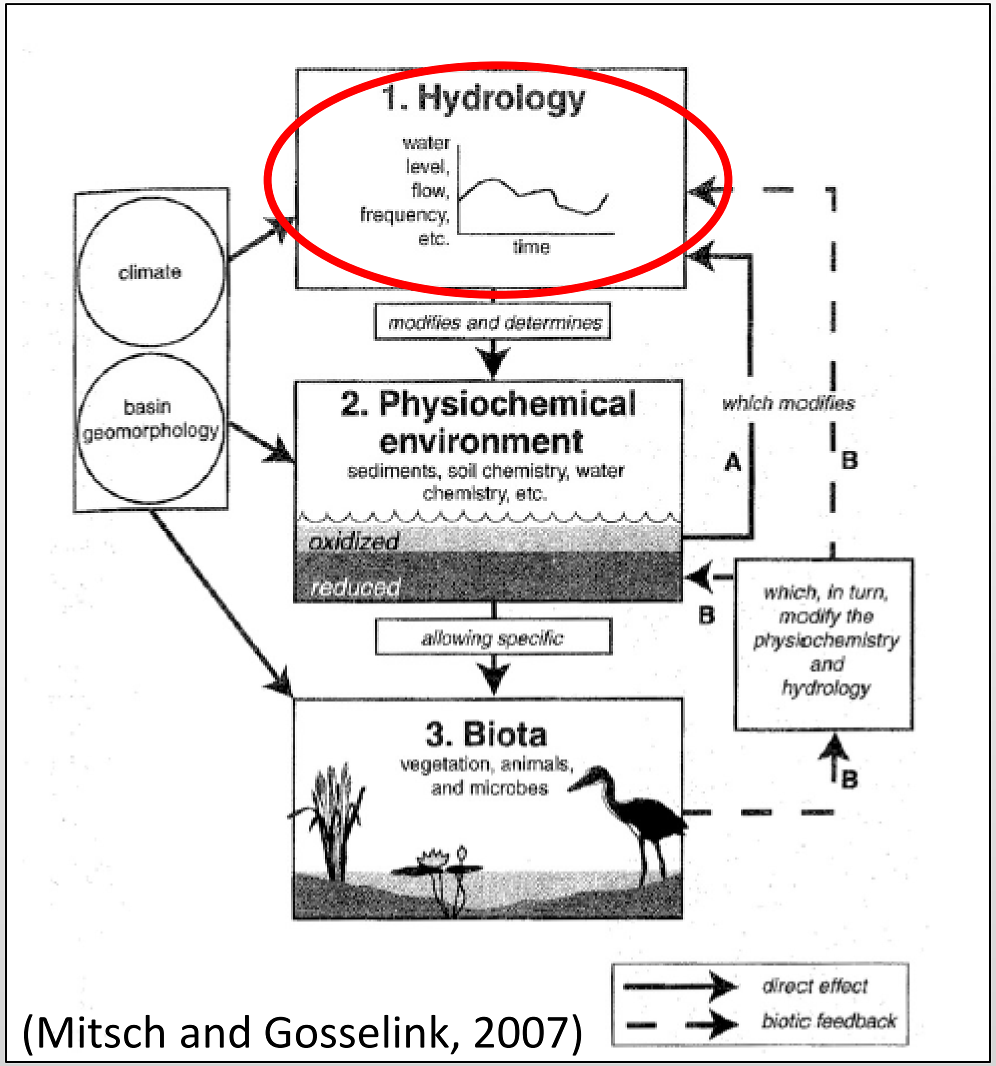
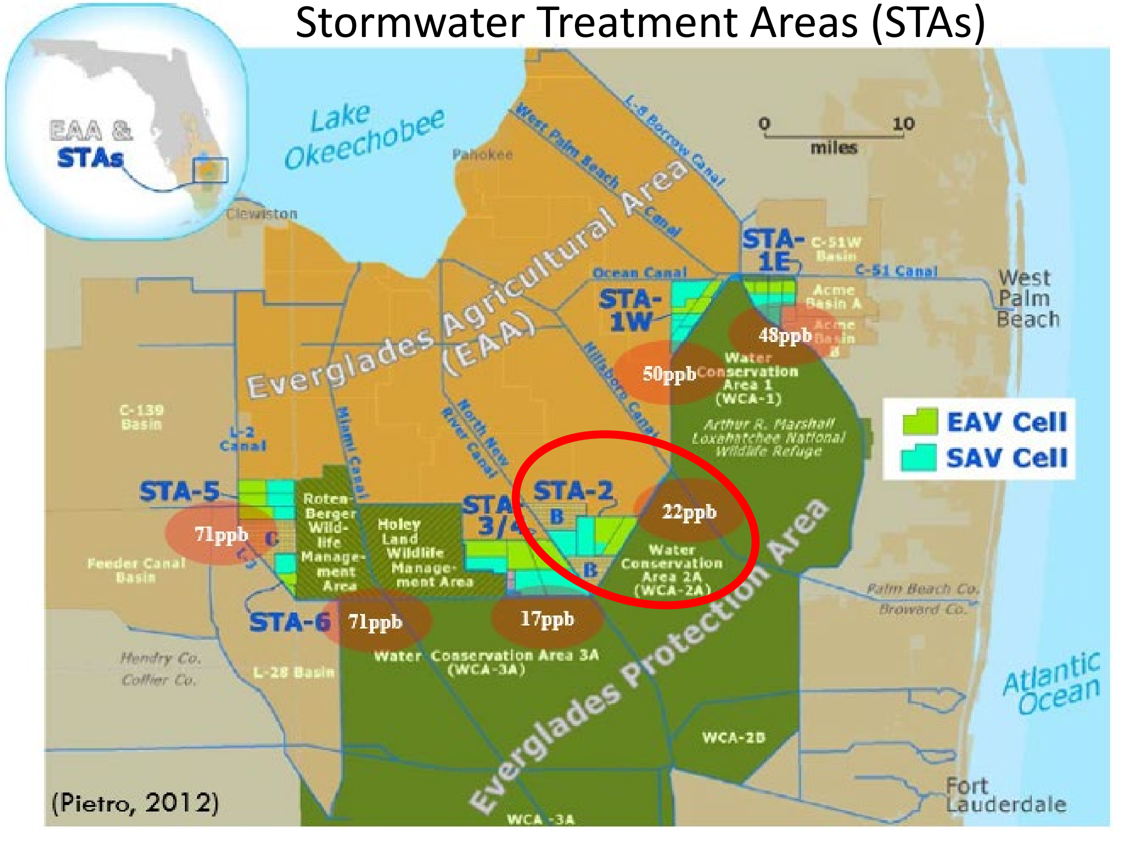
Introduction: Constructed Wetlands



(Mitsch and Gosselink, 2007)

Stormwater Treatment Areas (STAs)



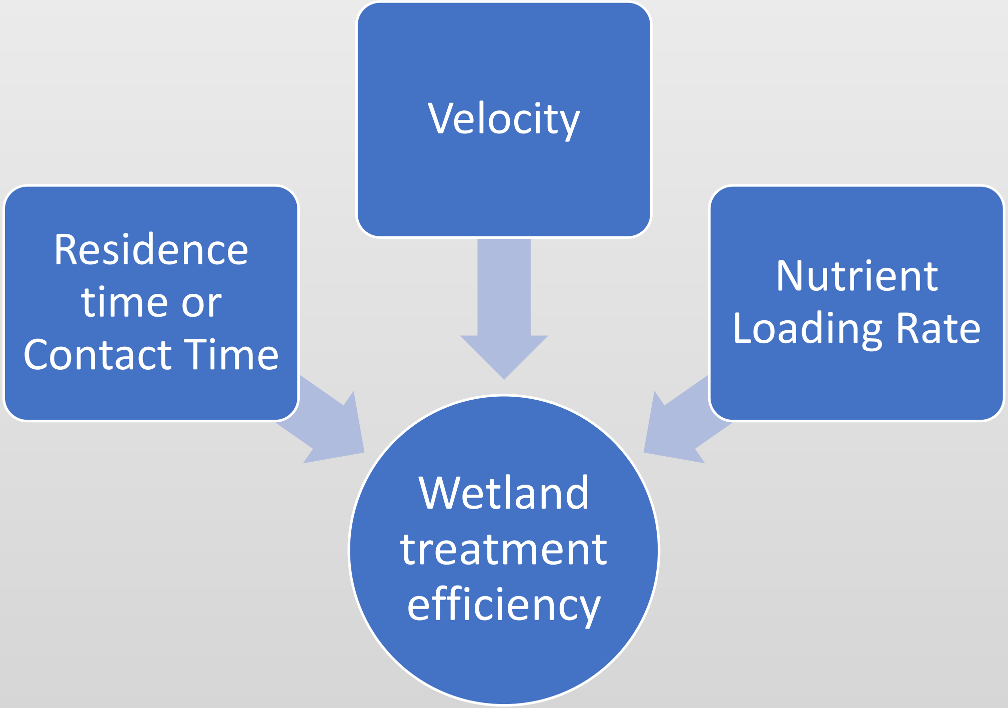
(Pietro, 2012)

Constructed wetlands are:

1. Human made
2. Low-tech water treatment systems
3. Take advantage of natural wetland processes between biota, soil, and water for nutrient removal (Vymazal 2010)

Wetland Hydrology: Transport

- Wetland treatment efficiency is dependent on water transport.
  - Transport varies temporally and spatially



Example: Vegetation

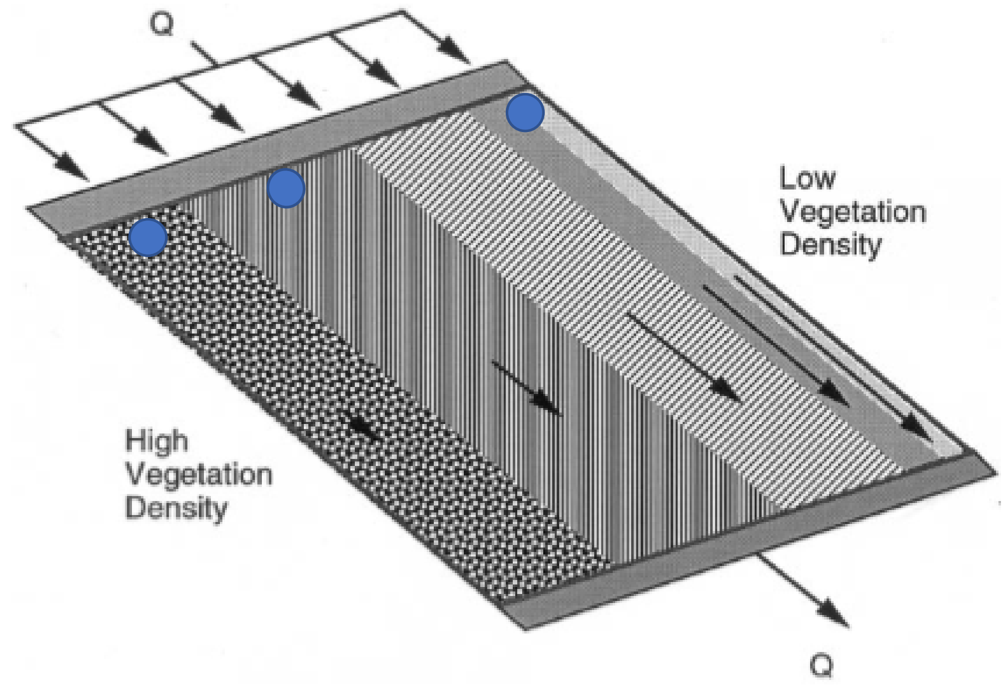


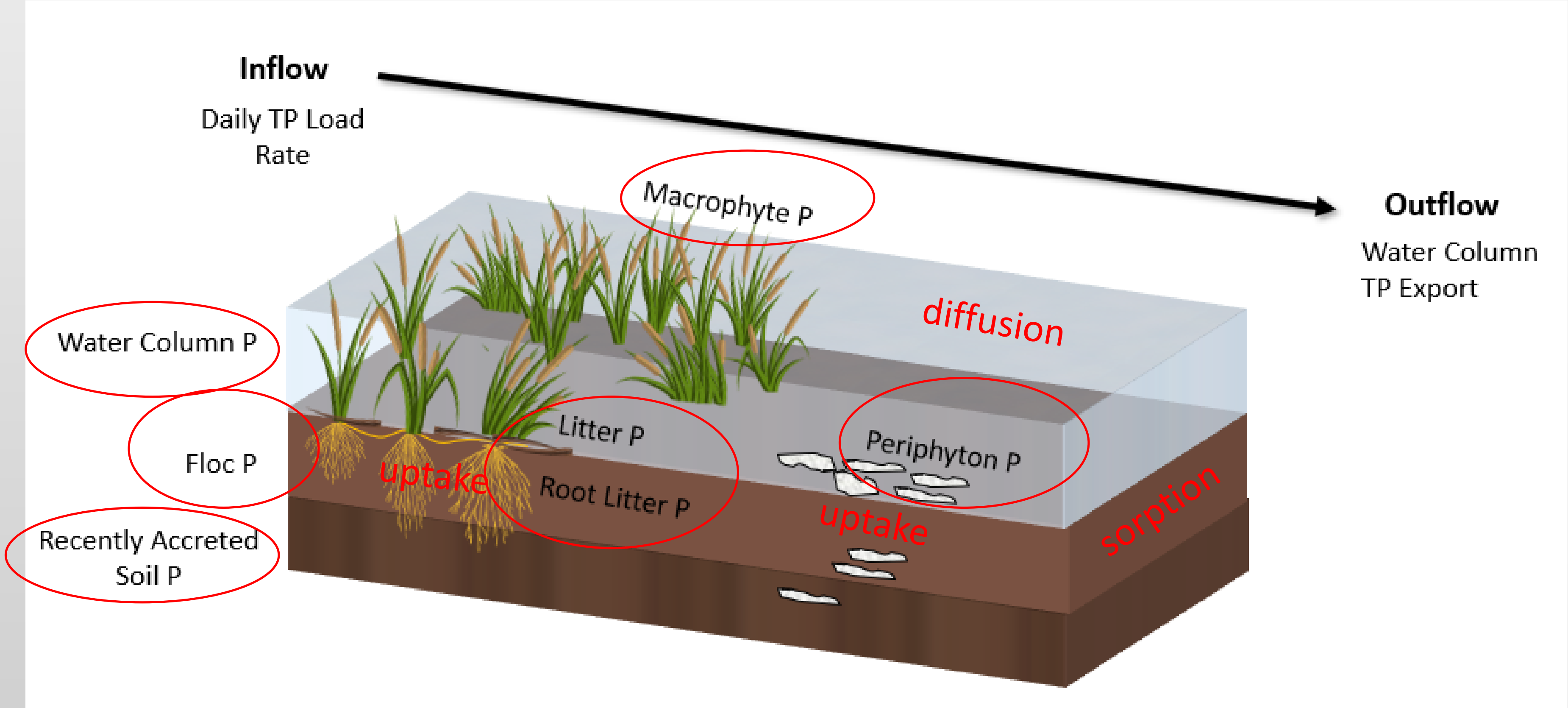
Fig. 4. Conceptual multi-channel flow pattern for example wetland.
(Kadlec 2000)

This creates slow and fast velocity flow pathways!

Wetland Hydrology: Transport

There has been a focus on modeling hydrology over biogeochemical cycling

- Due to spatial heterogeneity creating slow-fast flow paths
- BUT in low flow wetlands biogeochemical processes become important



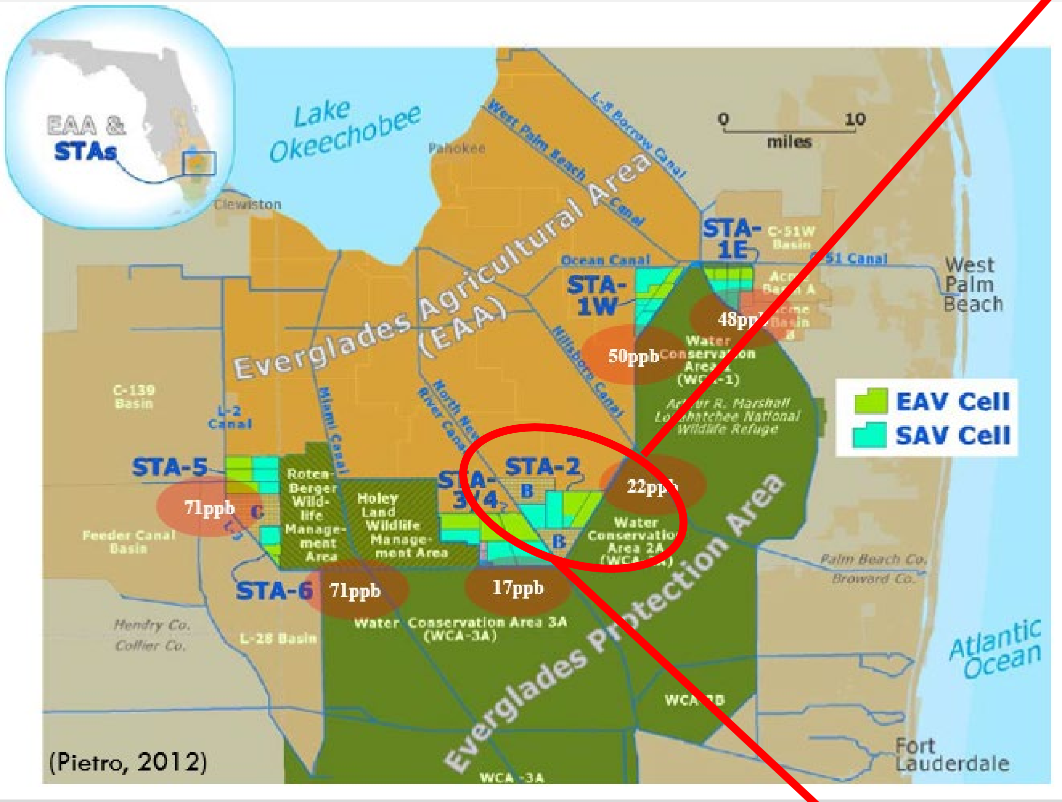
Research Objective:

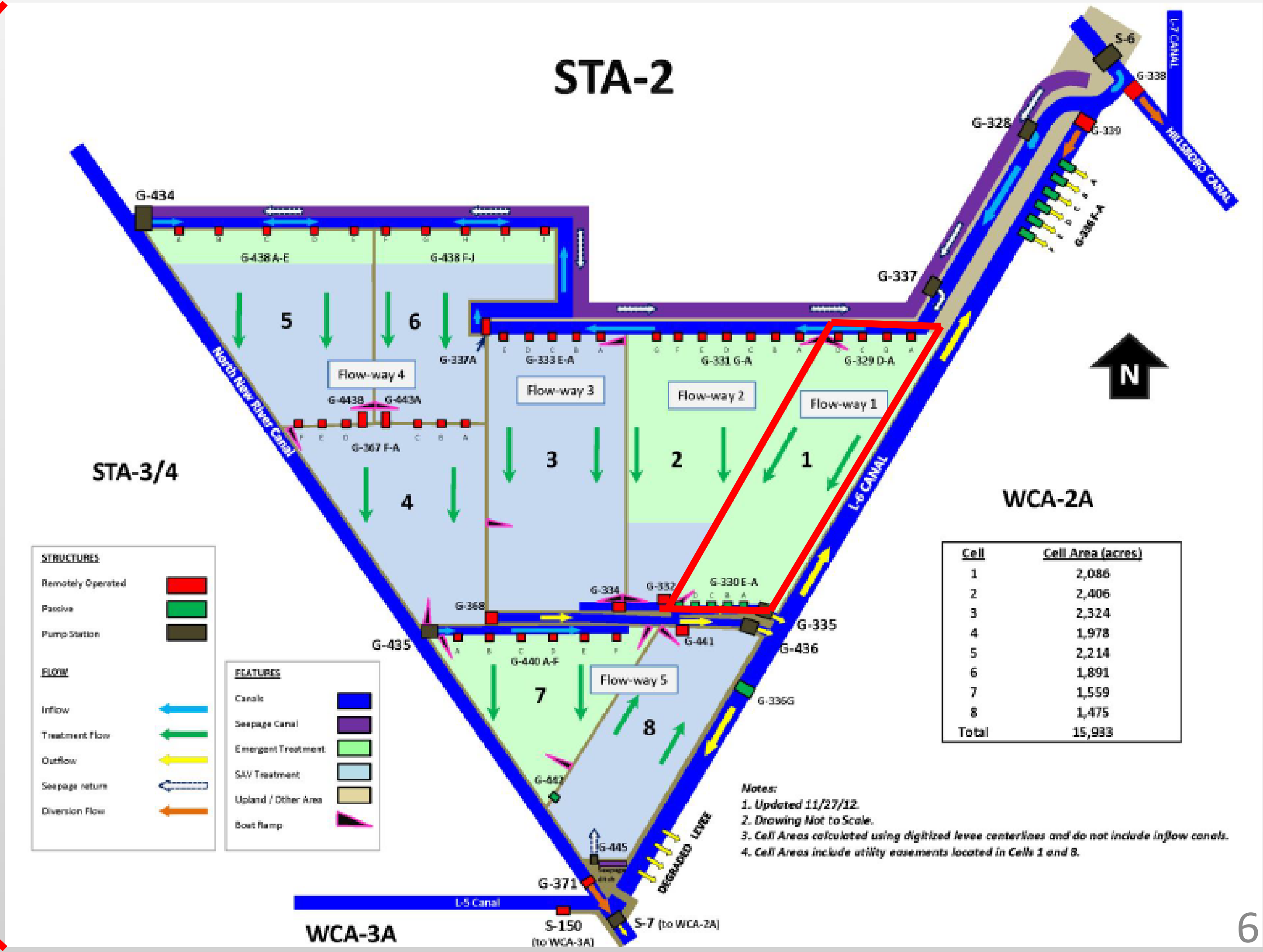
Explore the effects of flow rate on outflow Total Phosphorus (TP)

Hypothesis:

Differences in the numerical representation of hydrology will have larger effects on outflow TP concentration than differences in the biogeochemistry representation.

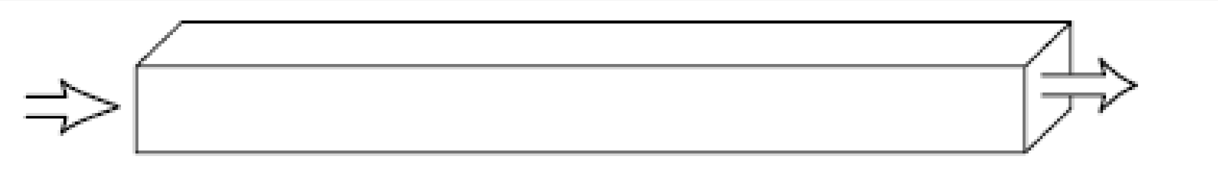
Study Site: Everglades STA-2 FW 1

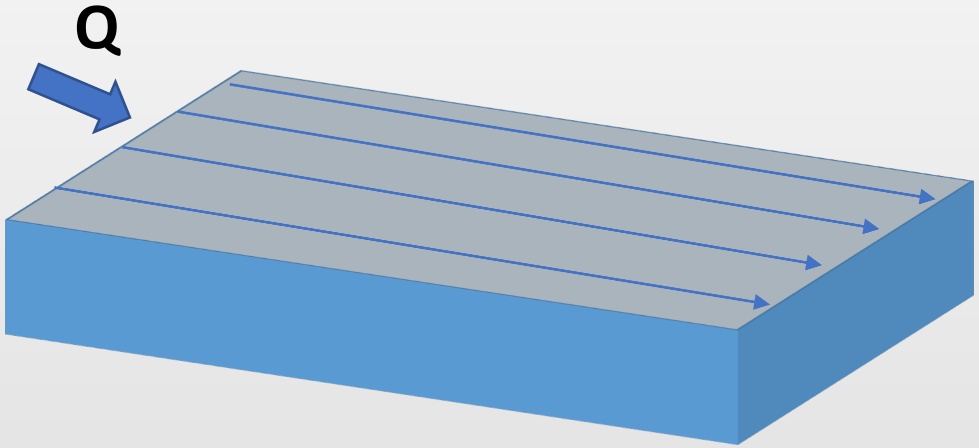




Methodology: Hydrology Models

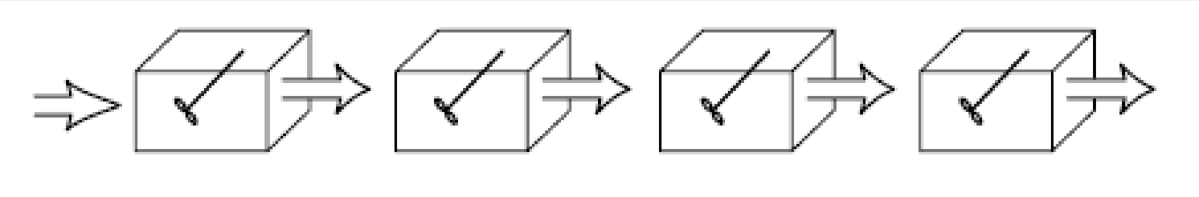
1) Plug Flow

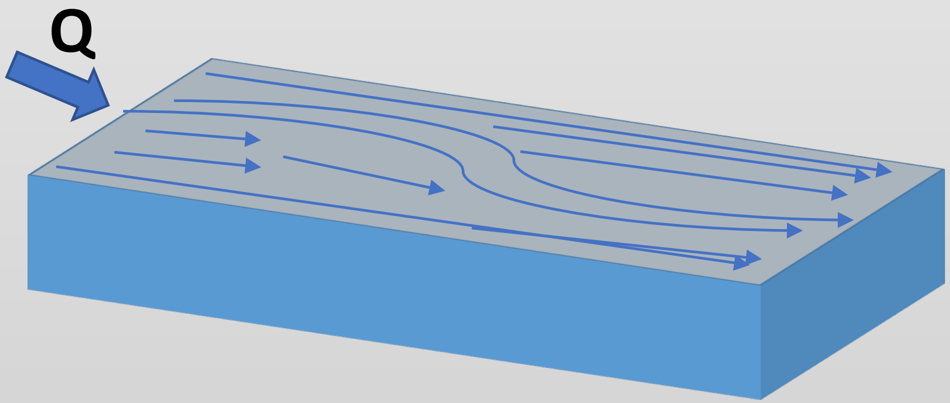




- Laminar Flow: No Mixing
- Constant Average Flow Rate or Varying Flow Rate (Q)

2) Tank In Series





- Turbulent-Laminar Flow: Mixing
- PDF of Hydrologic Residence Time
- Parcels of water can lag (Bykhovsky 2016)
  - Memory

(Kadlec & Wallace 2009)

Methodology: Biogeochemistry Models

First Order C* Model

- 2 parameters
- Describes uptake from all wetland components into 1 parameter called the uptake coefficient
- Considers a background TP concentration

Transient Storage Model

- 3 parameters
- Describes main wetland channel uptake and uptake from zones of slow flow (Transient Storage)

Spiraling Model

- 43 parameters
- Describes the physical, chemical, biological processes in a wetland
  - Resuspension, Settling, Soil Burial, Sorption, Uptake, Decomposition

Methodology: Experimental Set-Up

Hydrology Model	Biogeochemistry Model
Plug Flow: Varying Q	Spiral, Transient Storage, First Order Uptake
N-Tank In Series (relaxation=13d)	Spiral, Transient Storage, First Order Uptake

Inputs :

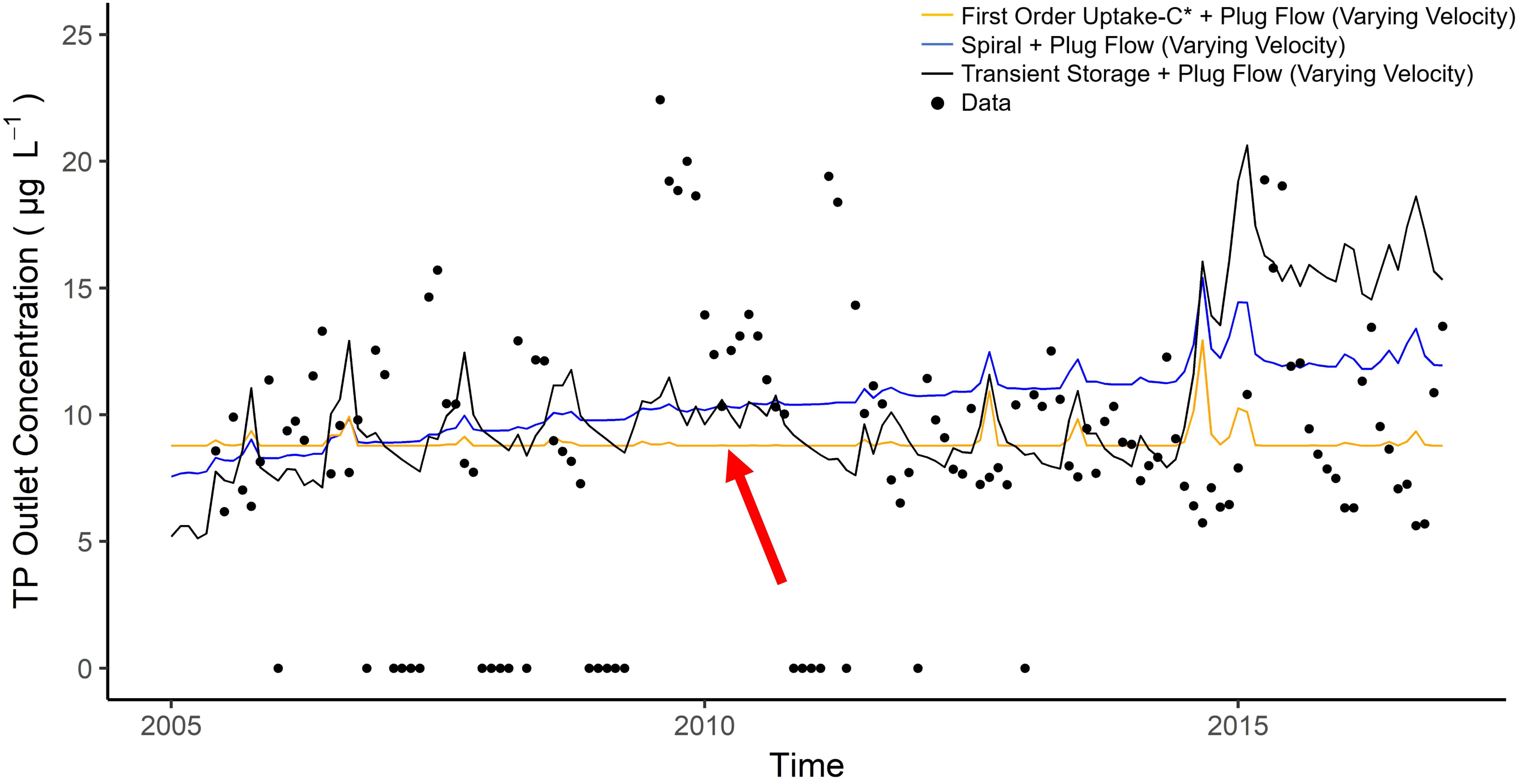
- Inflow TP concentrations
- Hydrologic data from STA-2 FW 1
  - 06/2005-12/2016

Hydrology + Biogeochemistry Model →

Outputs :

- Outflow TP concentrations

Differences in Uptake With Plug Flow: Spiraling Model, Transient Storage, and First Order-C* Uptake



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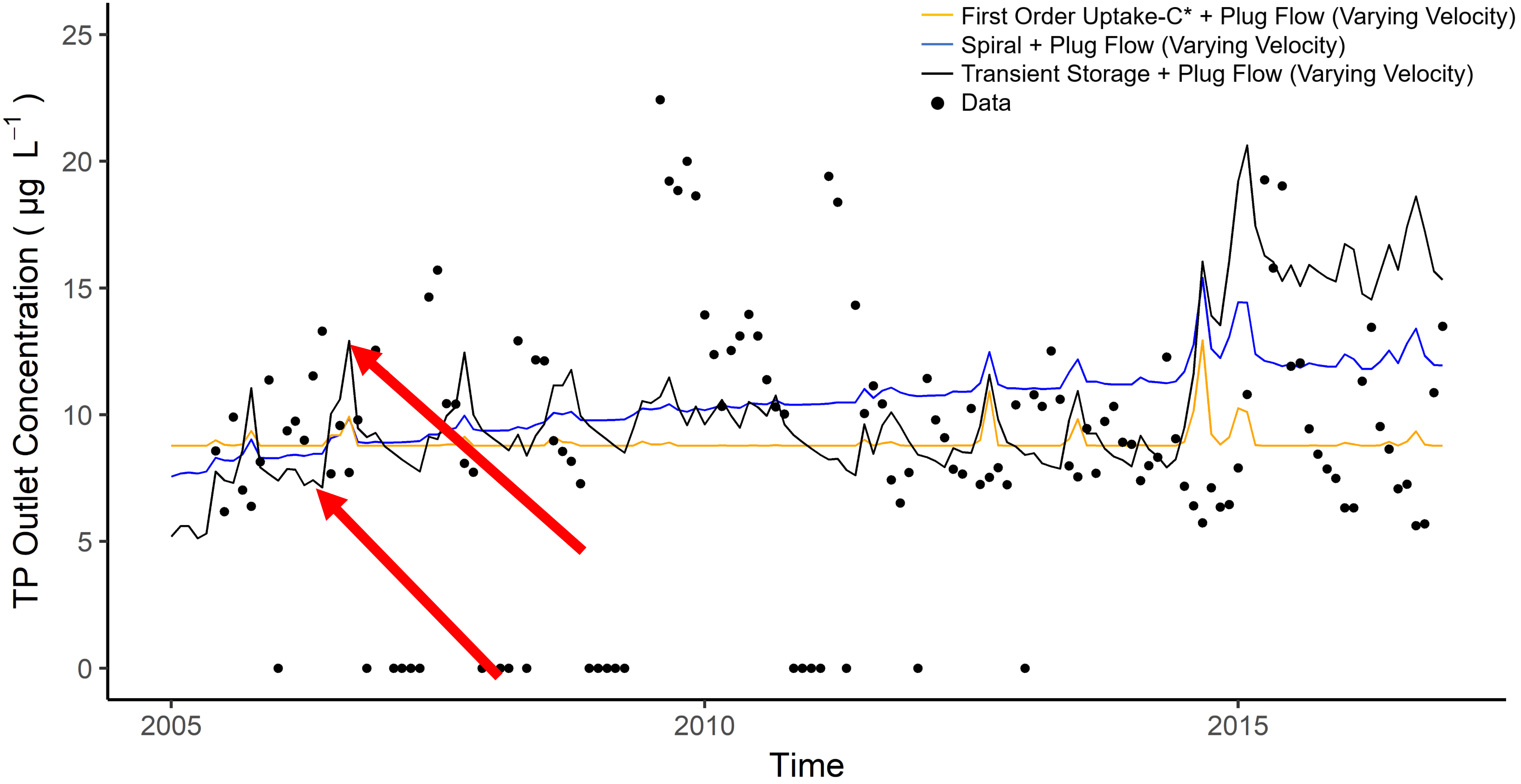

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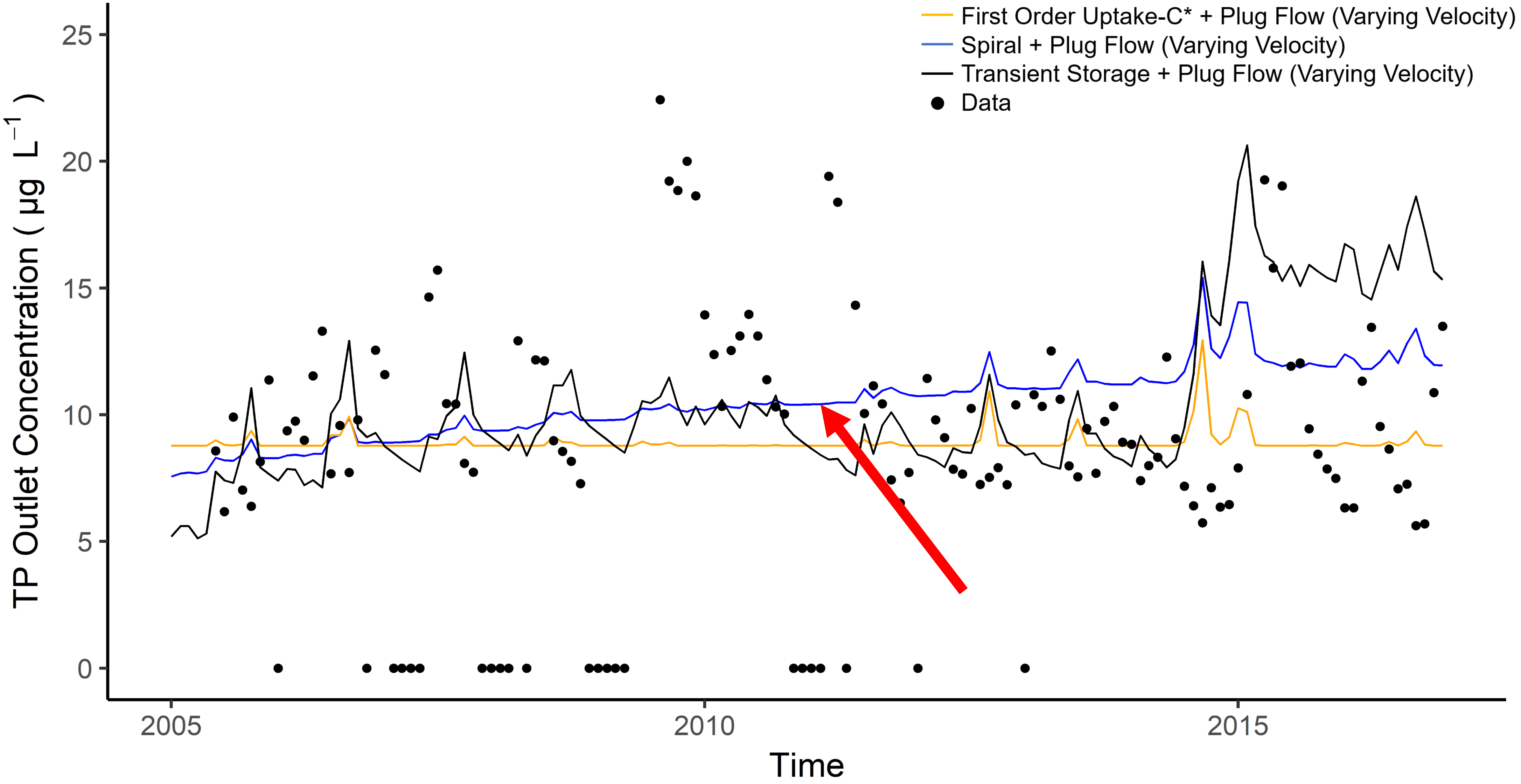
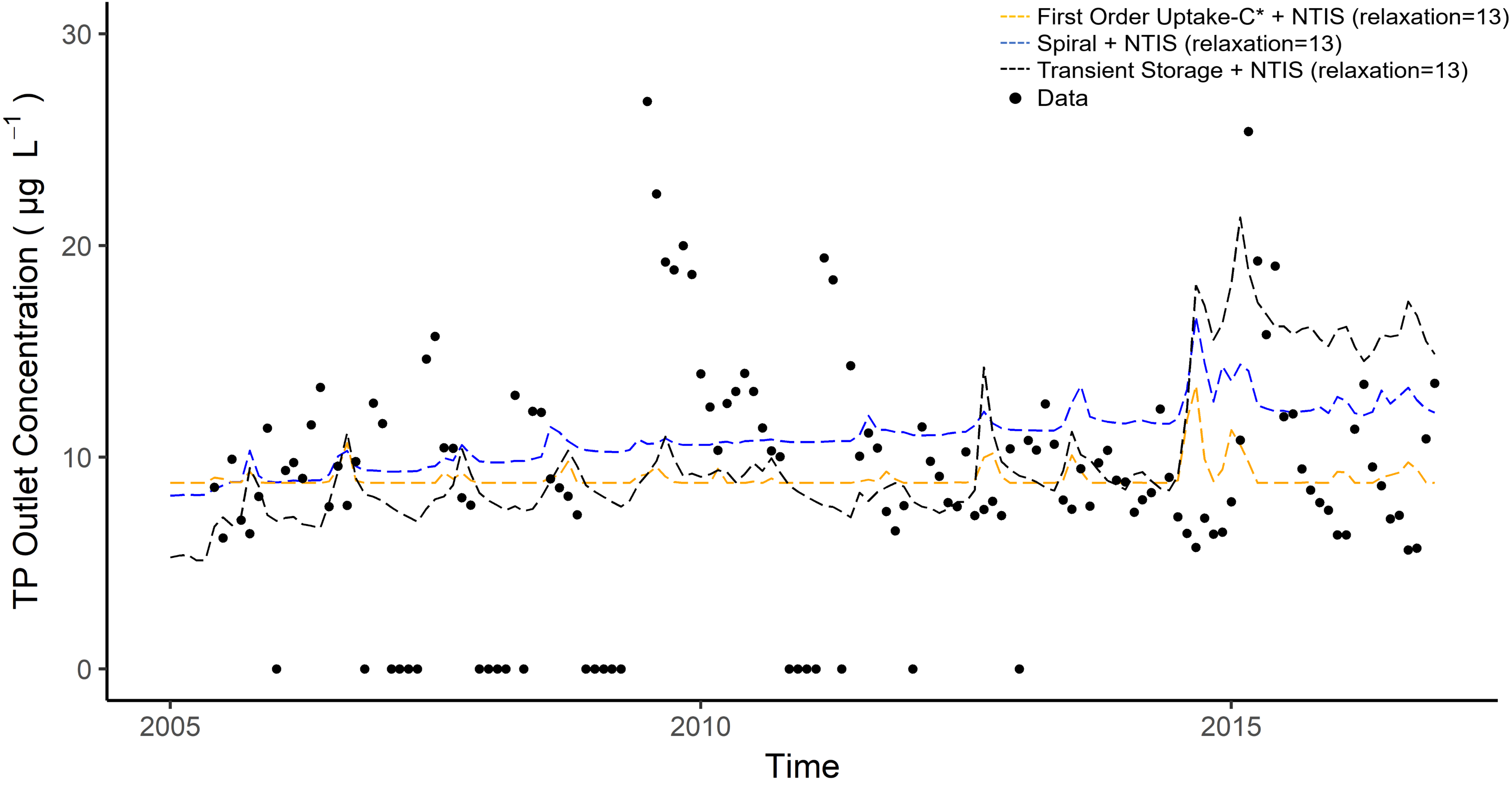
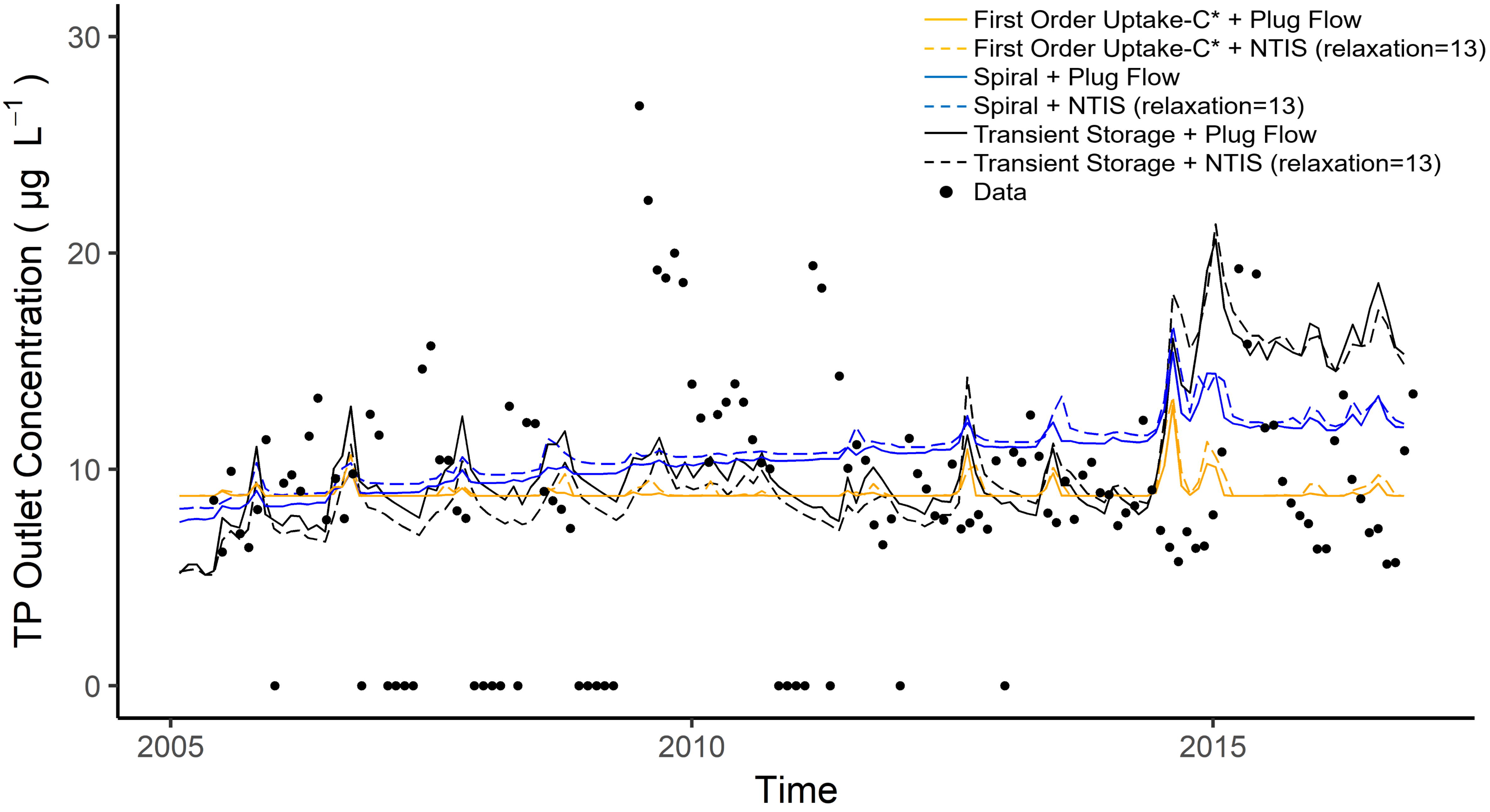


Differences in Uptake With NTIS: Spiraling Model, Transient Storage, and First Order-C* Uptake



Model Comparison: Differences in Uptake & Hydrology



Summary

1. All model combinations are in the ballpark for simulating TP concentrations, so it really depends on the research objective.

2. The different numerical representations of flow lead to similar results.

3. Modeling biogeochemistry in low flow wetlands to understand treatment efficiency is just as important, if not more critical than modeling hydrology.