Process Rates Parameterization in a Blackwater River Estuary - The St. Johns River, FL

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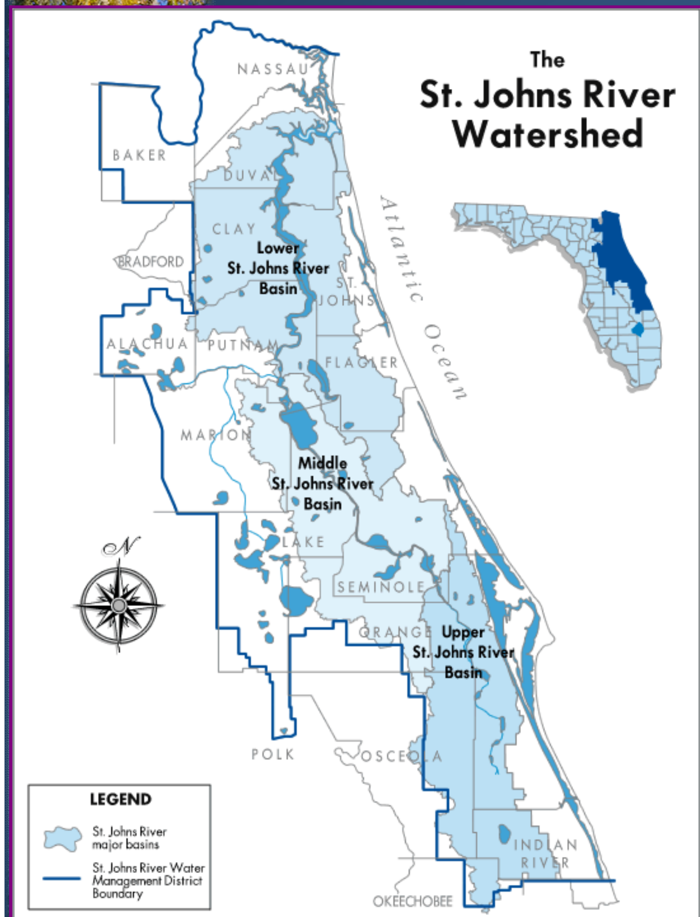
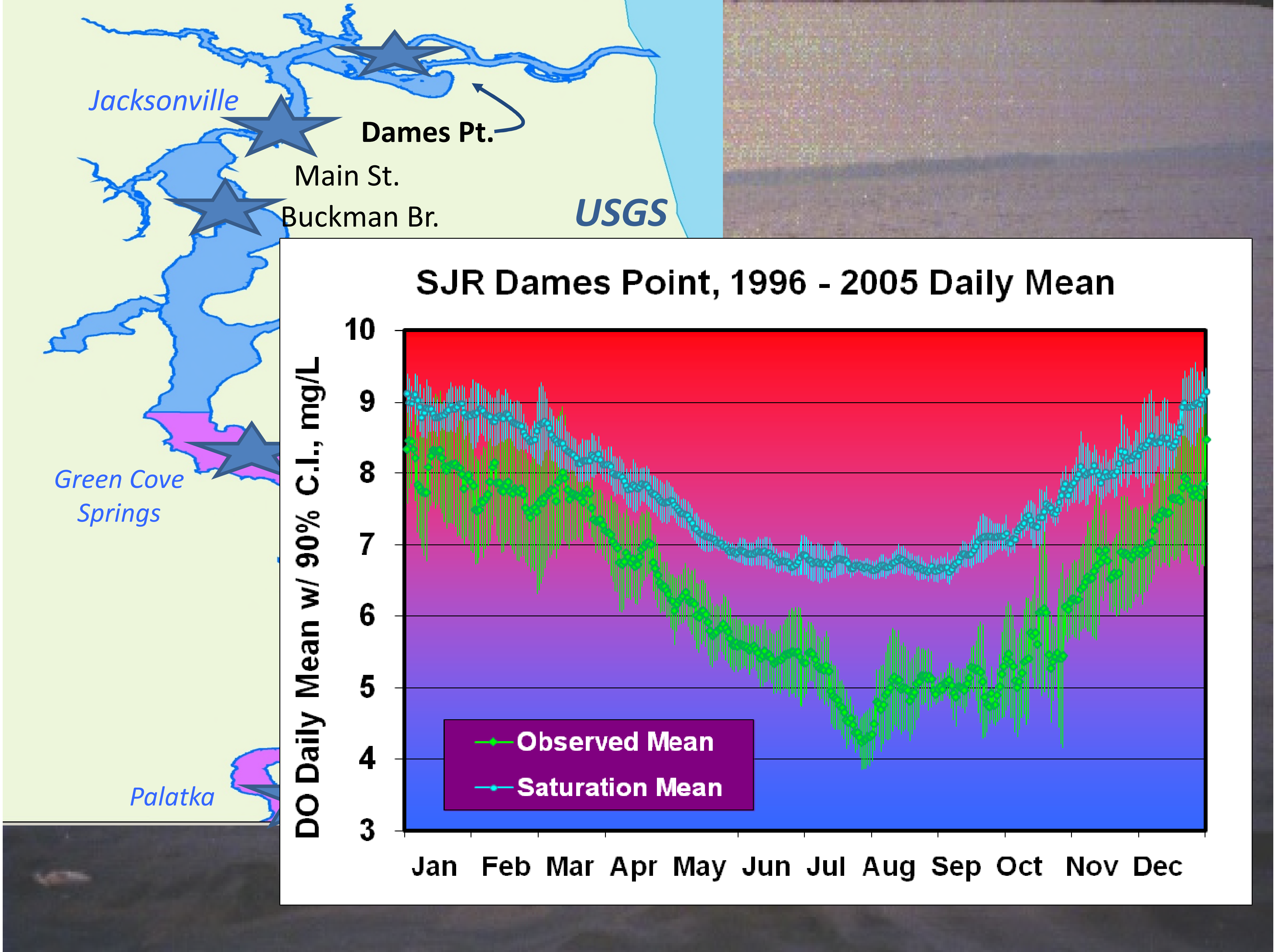
St. Johns River WMD

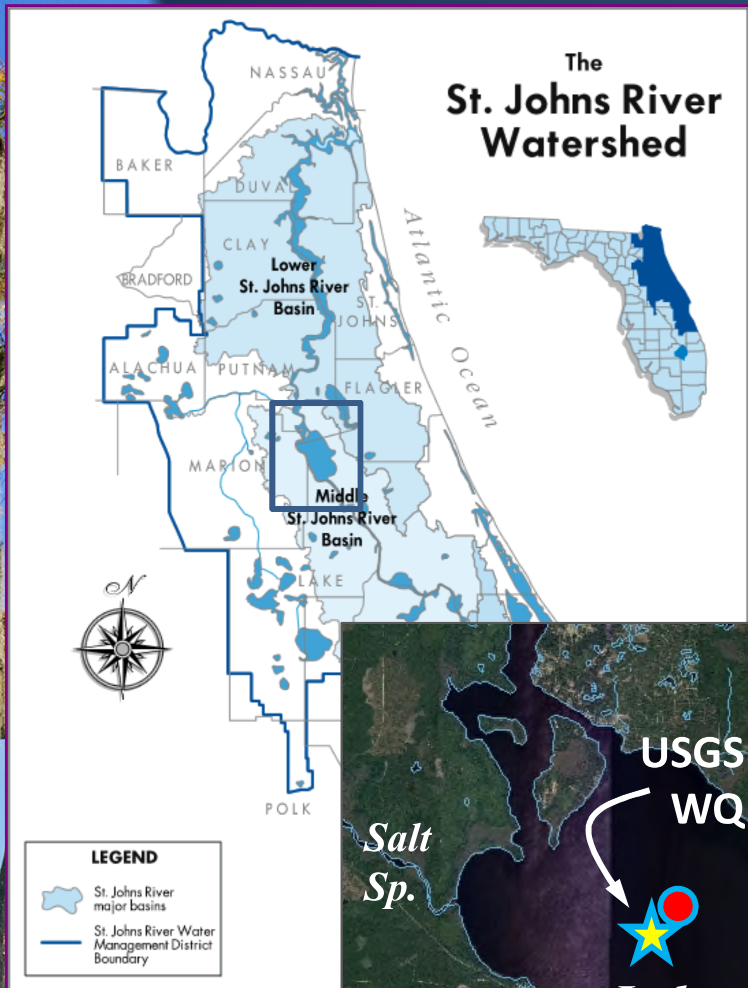
SJRWMD Surface Water Quality Monitoring at the "Sub-Ambient" Temporal Scale

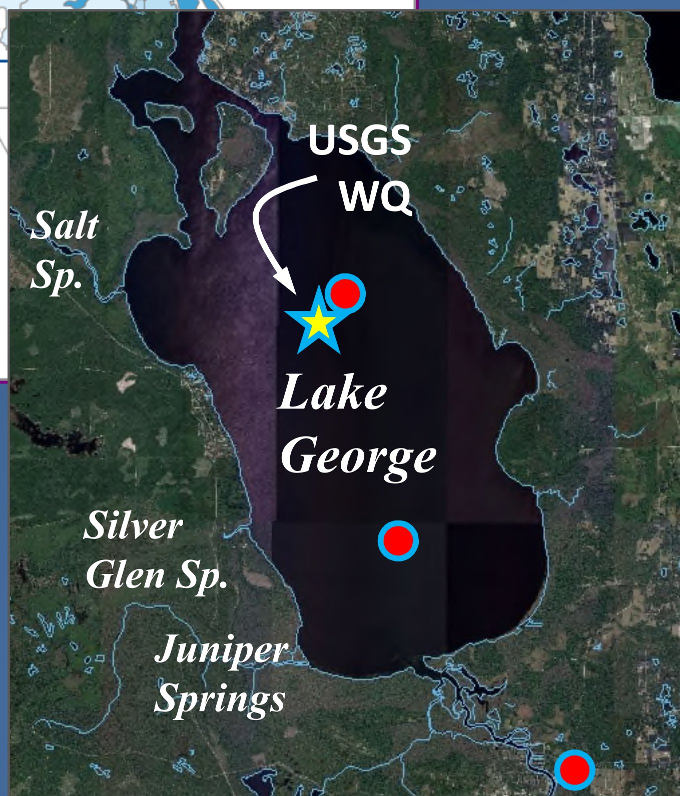


- Automated Samplers – Since 1987; used to characterize urban and ag stormwater, treatment efficiencies
- *In-Situ* Autonomous Sensors:
  - First St. Johns R. networks established mid 1990s (USGS, NOAA, NOS)
  - Provided data stream in sync with hydrologic, meteorological drivers
  - Indispensible for time-varying hydrodynamic and WQ model calibration necessary for dynamic river estuary settings


Jacksonville
Dames Pt.
Main St.
Buckman Br.
USGS
Green Cove Springs
Palatka
SJR Dames Point, 1996 - 2005 Daily Mean
DO Daily Mean w/ 90% C.I., mg/L
10
9
8
7
6
5
4
3
Observed Mean
Saturation Mean
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Lake George

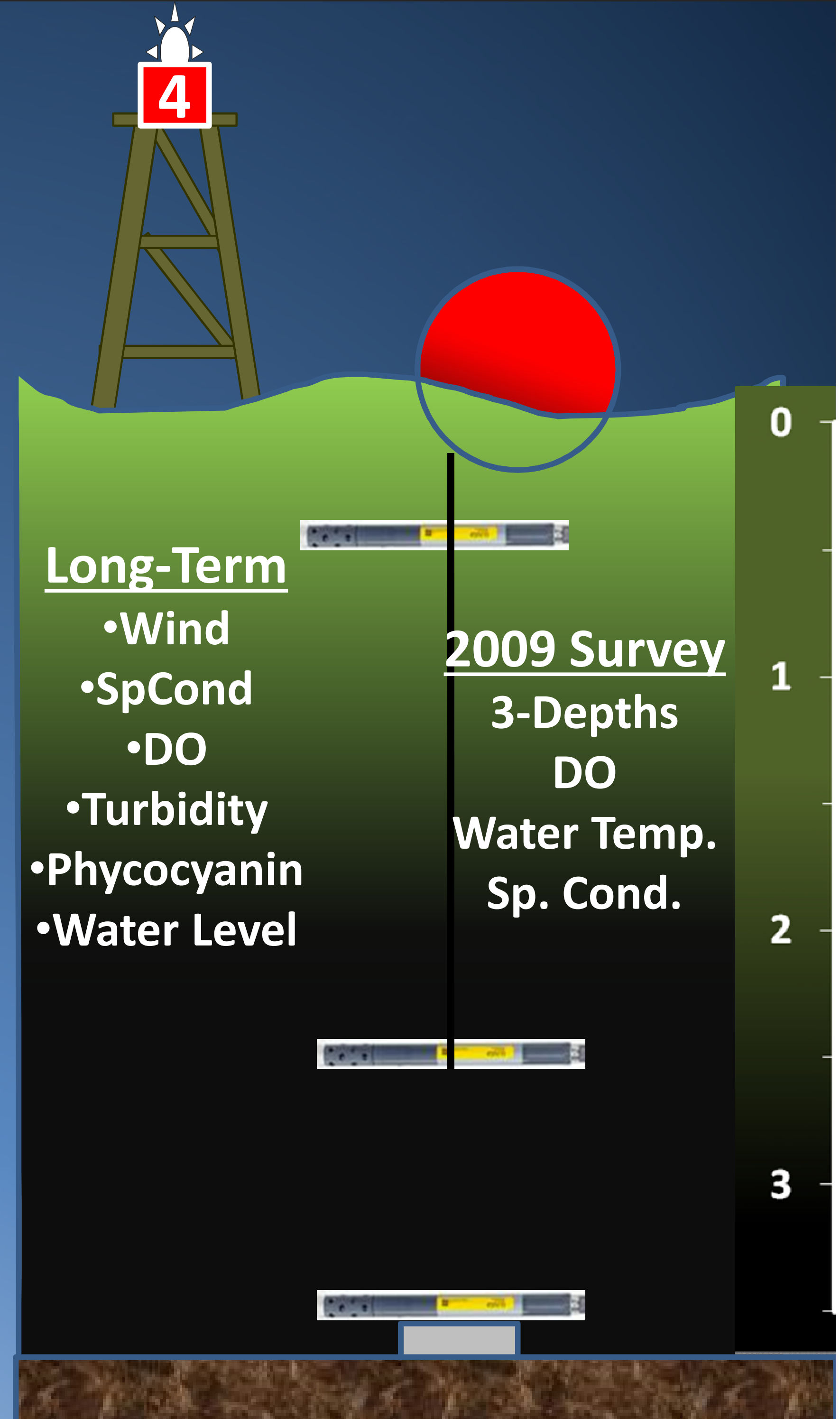




- Florida's 2nd largest lake
  - 210 km^2 (46K acres), uniform ≈ 3.5 m depth
  - Head of tide for SJRE
  - CDOM limits photic zone
  - 95% of load from upstream; adjacent inflow primarily springs
- Focus for Water Supply Impact Study effects on phytoplankton
- Eutrophic - Recently listed as nutrient impaired, needing TMDL

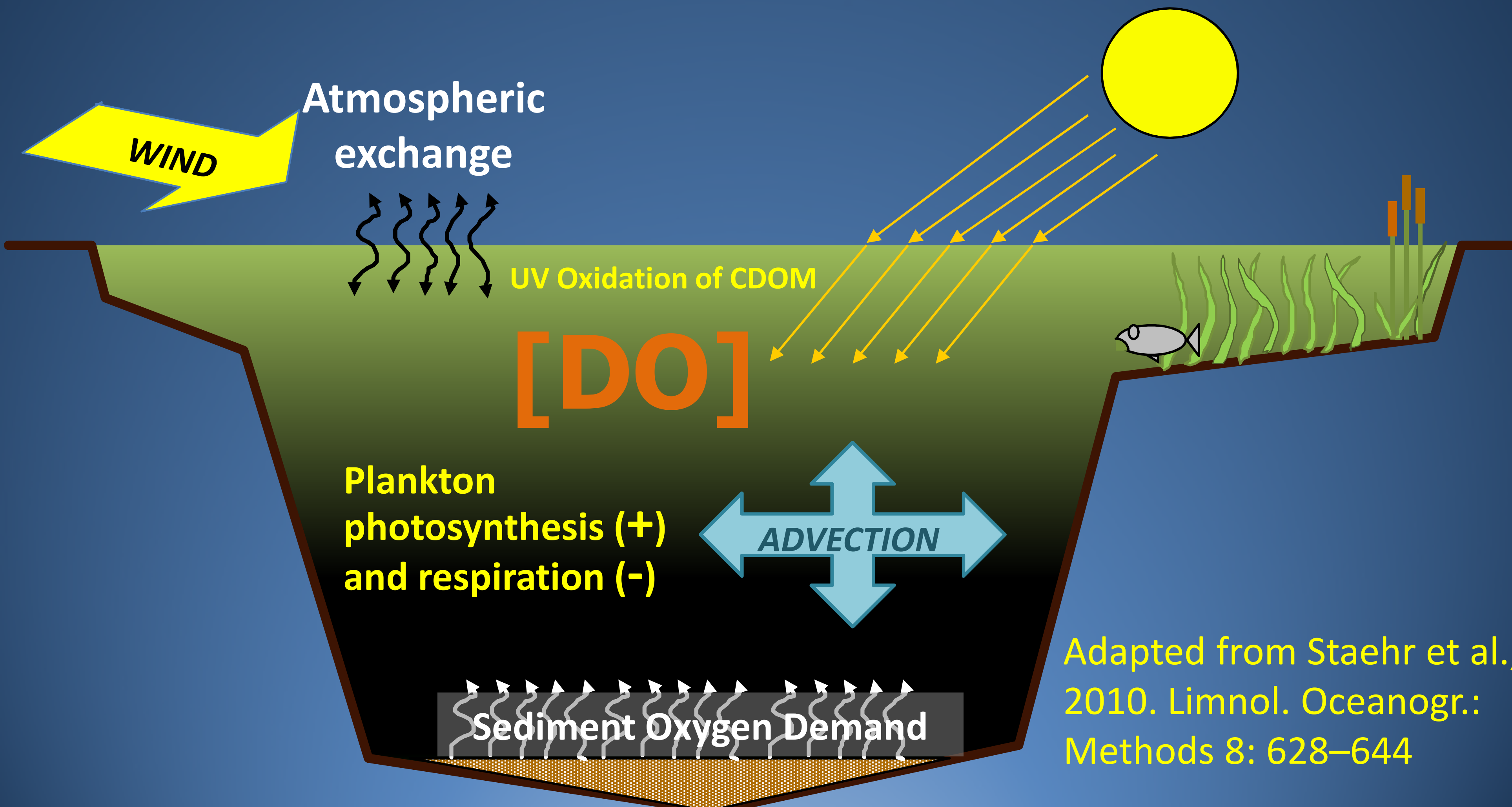
Lake George
CM Programs

- Long-Term (USGS) -
  - Bloom peaks, phytoplankton biomass, TMDL targets compliance
  - Sediment re-suspension
- 2009 Survey Objectives:
  - Vertical stratification and bottom water anoxia - strength, persistence, setup and disruption
  - Patterns in R and GPP through bloom cycles



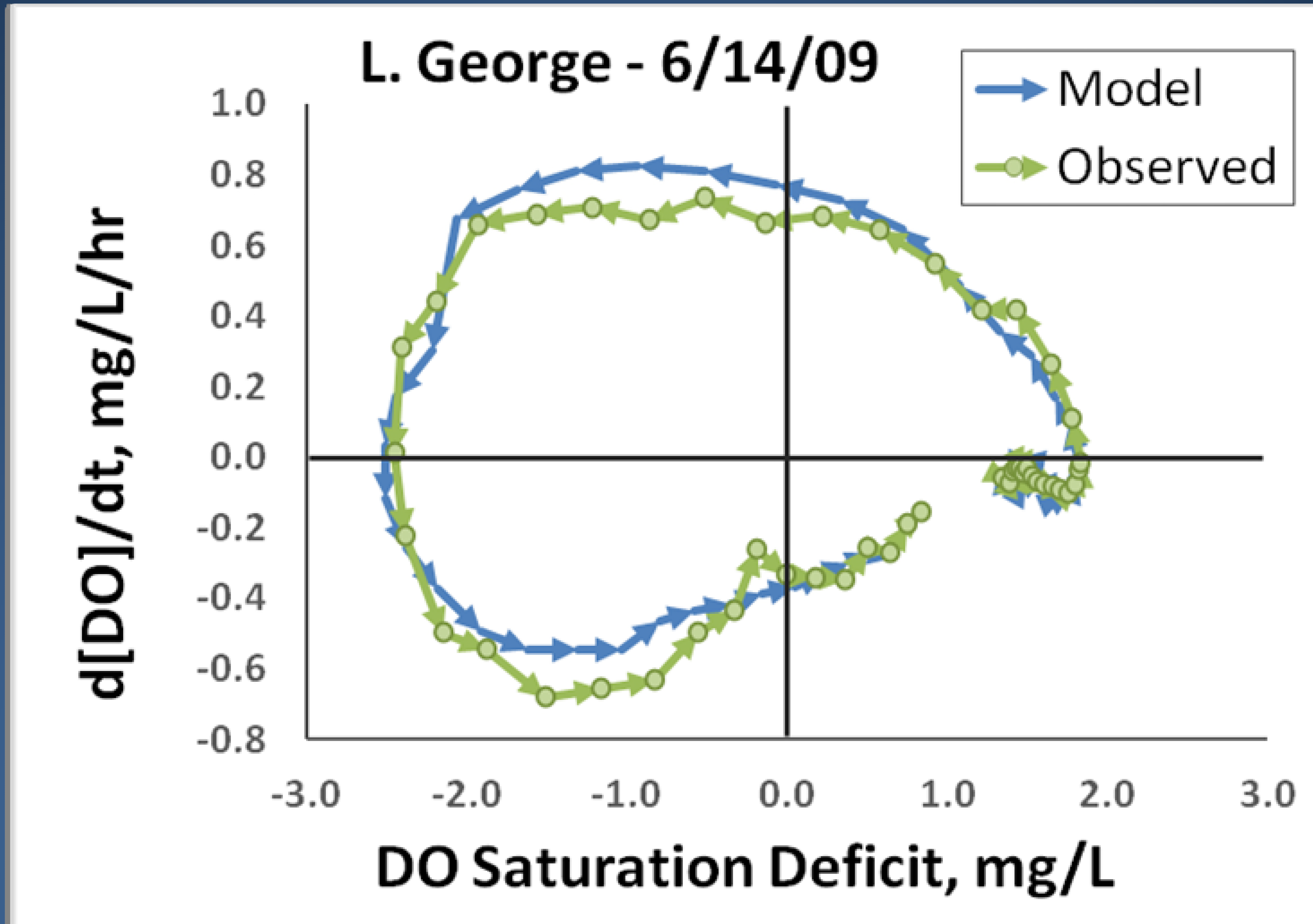
Conceptual Model – Lake Productivity

- Shallow; limited temperature-density stratification
- SOD, underwater light are factors in water column DO balance
- Uncertainty regarding various fluxes can make explicit computations difficult



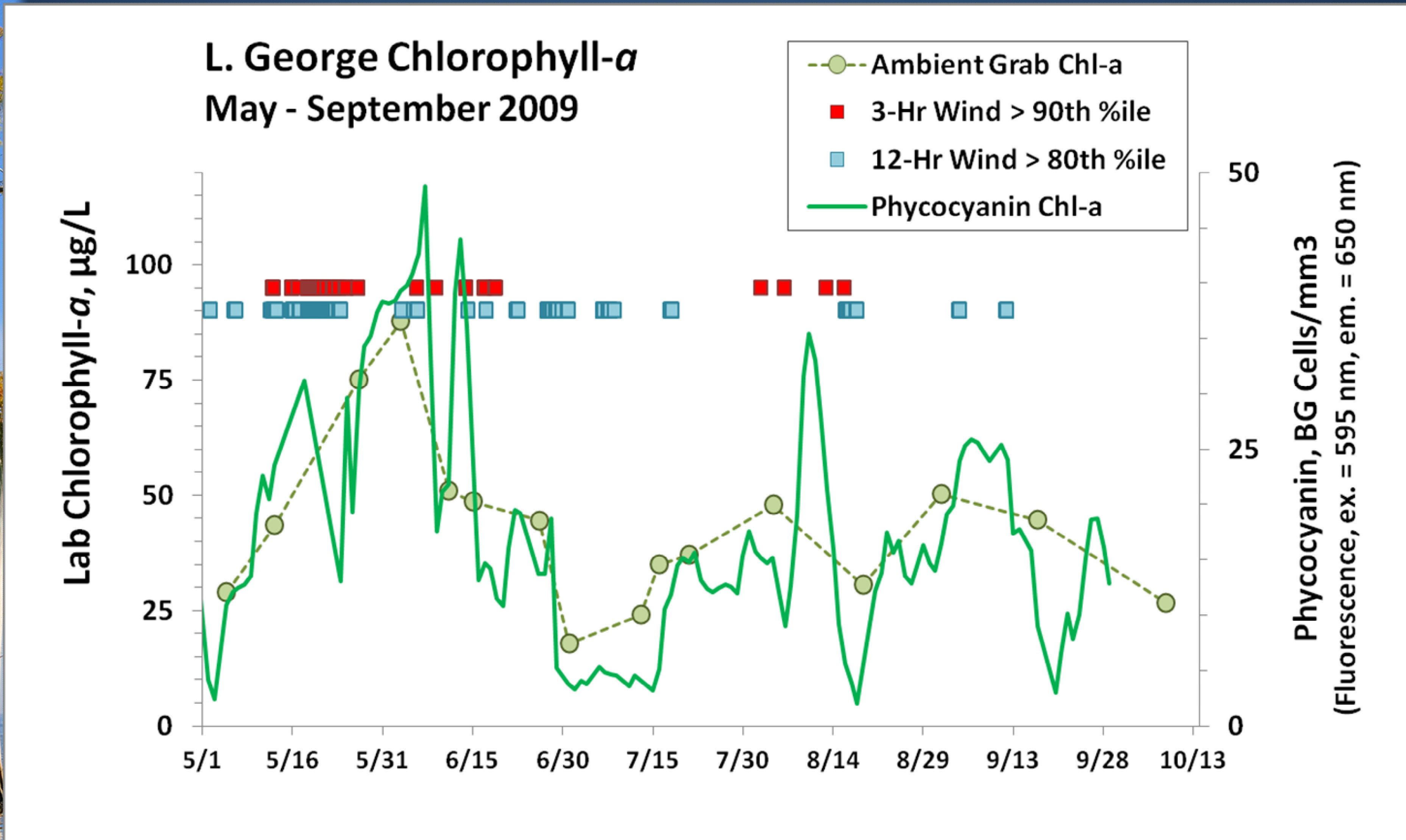
Adapted from Staehr et al., 2010. Limnol. Oceanogr.: Methods 8: 628–644

Lake George Productivity Parameters - Methods



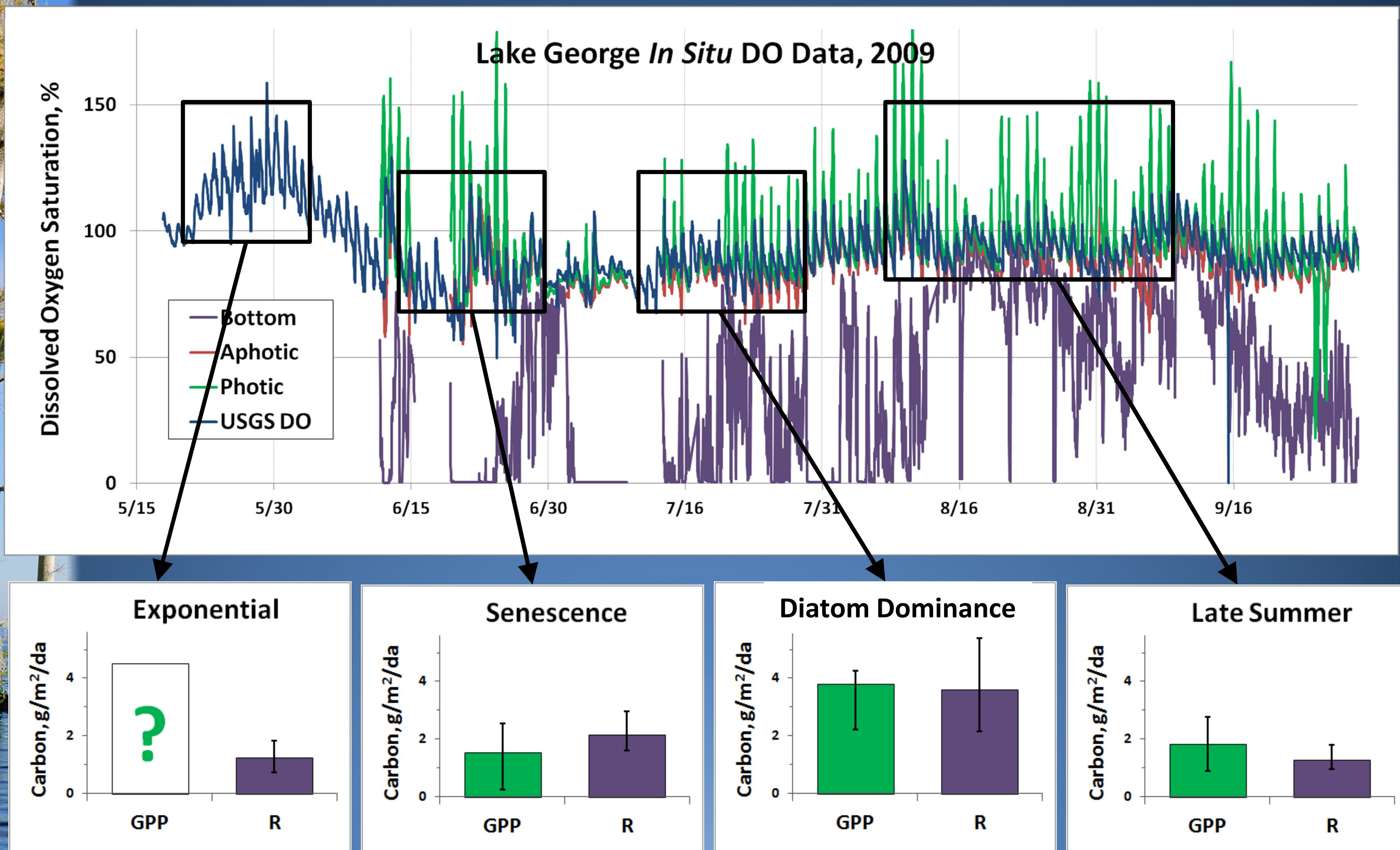
Vachon and Prairie, 2013. Can. J. Fish. Aquat. Sci. 70: 1757-1764
Staehr et al., 2010. Limnol. Oceanogr.: Methods 8: 628–644

Lake George – Event Scale Processes

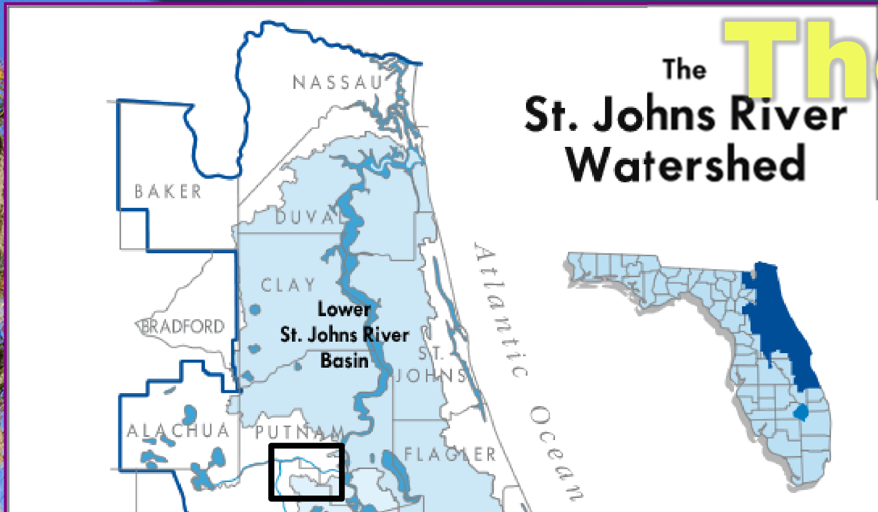


L. George – Phytoplankton Productivity

Syncing Standing Stock w/ Productivity

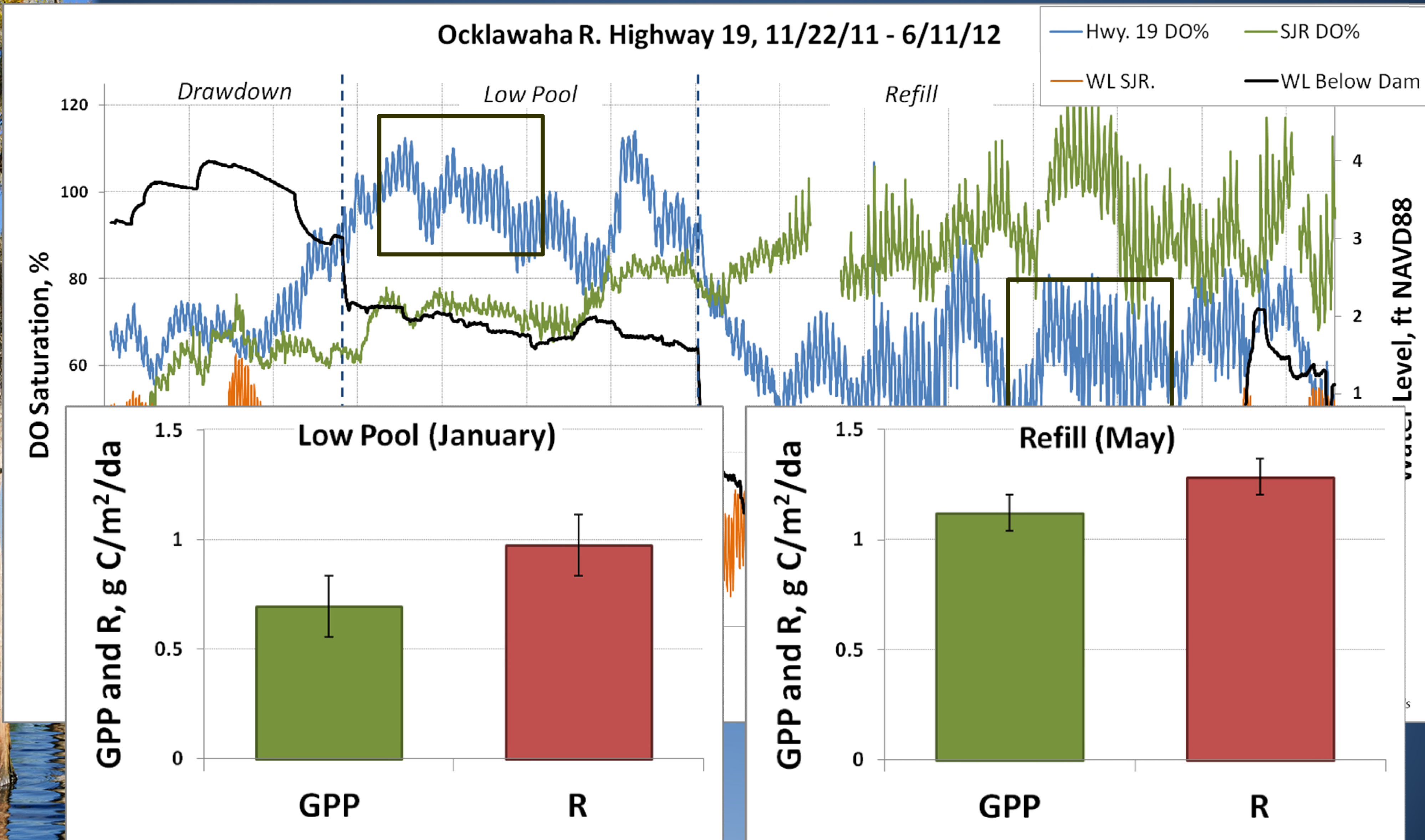


The Ocklawaha River



- One of Florida's Unique artesian spring-fed rivers, impounded since 1968 by Kirkpatrick Dam
- Invasive aquatic plants management: reservoir draw down every 3 years
- During drawdowns:
  - Elevated N and P
  - Algal blooms
  - Low DO
- What are processes that lead to adverse WQ?

Rodman Reservoir Drawdown 2012
In Situ DO



Primary Producer Community Structure Changes in Florida Springs

- **Problem: Dramatic shifts in primary producer communities from rooted macrophytes to benthic algae and periphyton, with concomitant changes in fish and invertebrate communities[1].**
- **Increases in NOx implicated as a driving factor**
- **Fundamental question – what is NOx processing in springs, how does it affect primary producer structure and function?**

[1]*(Scott et al., 2004; Munch et al., 2006).*

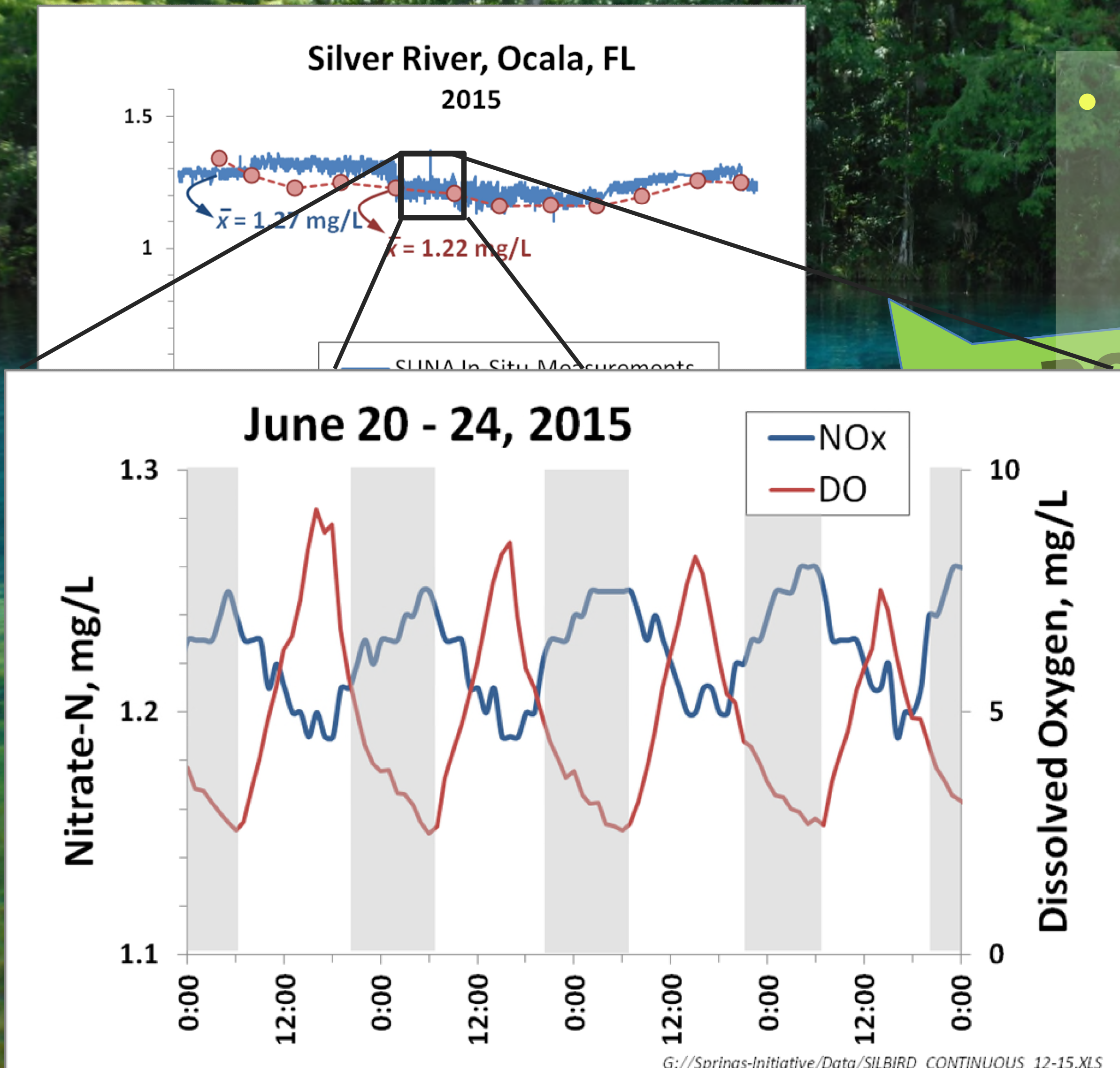
SJRWMD – University of Florida Springs Protection Initiative

Silver Springs

- Overall Objectives:
  - N loading sources, pathways and processes
  - Assess drivers of productivity changes, primarily NO_X
- Focus on Silver River (Alexander Springs as reference)
- Physicochemistry research elements:
  - Sources and Sinks of Nutrients
  - Nitrogen Dynamics and Metabolism

Google

Spring Run Whole Ecosystem NO_3 Processing Assessment Conceptual Approach*



- Continuous DO and NO_X permit simultaneous measure of production & N assimilation
  - C:N indicate primary producer dominance
  - Longitudinal network allows reach segment calculations
  - Mesocosms to assess assimilation w/o replenishment

*Cohen et al, 2011, SJRWMD Technical Publication
Heffernan and Cohen. 2010, *Limnol. Oceanogr.*, 55(2)

In Summary . . .

- CM data essential for describing events and processes operating at sub-ambient (hours to weeks) time scales.
- Necessary or extremely valuable when assessing compliance with magnitude-duration-frequency criteria
- Pre-deployment data quality objectives should consider:
  - Numerical precision
  - Time step
  - Ancillary measurements
  - Site heterogeneity
- Data sets get big – need for processing algorithms and automated non-conformity detection. Challenges:
  - Time format, sync and interval when merging data sets or applying rate coefficients
  - Smoothing and filtering may be necessary for noise
  - Rules for “cherry picking” should be defined


ST. JOHNS RIVER
SJR
WATER
MANAGEMENT
DISTRICT

Submersible UV Nitrate Analyzer (SUNA) made by the Satlantic Corporation (Halifax, Nova Scotia)

Measurement interval 15 minutes

gross primary production (GPP) and ecosystem respiration (R) in units of g O2/m2/d

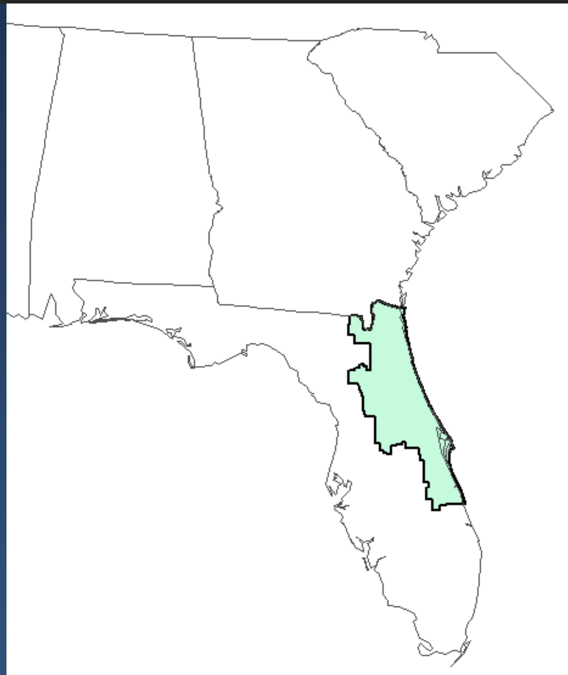
Reaeration is the most uncertain parameter

Biological processes dominate diel N pattern

Heffernan, J.B. and M.J. Cohen. 2010. Direct and indirect coupling of primary production and diel nitrate dynamics in a subtropical spring-fed river. Limnology and Oceanography 55:677-688

N-saturated systems – Primary producers do not assimilate N at night – Underlying assumptions: Since all diel variation is ascribed to autotrophic uptake, the remaining N loss (i.e., the difference between observed concentrations and the flow-weighted input concentration) is ascribed to heterotrophic removal, the bulk of which is denitrification dissimilatory pathways further parsed through stable isotope fractionation

St. Johns River Water Management District



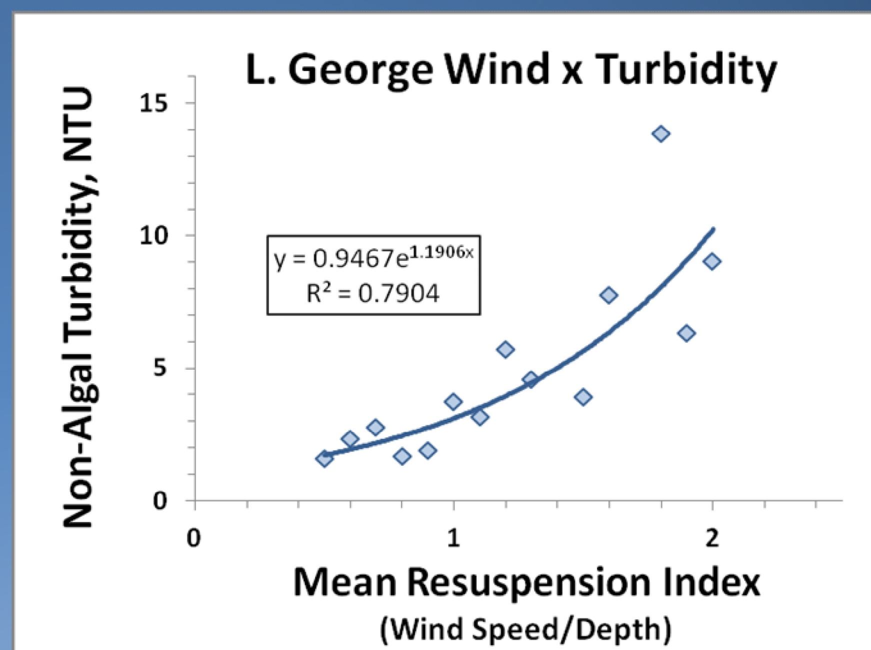
Lake George –
Surface sonde assumed to represent Photic zone; 2/3rds depth aphotic (diagram); Include USGS, as representative of mid aphotic, use to extrapolate to antecedent bloom; assume daily increases in mid depth DO due to photic zone diffusion, not in-situ productivity; instrument types
NEP = GPP – R; Assume R constant, GPP determined from daytime O2 rate based on data (Standard approaches described by Cole and Caraco (1998), Staehr, Coloso et al. (2008), and Vachon
Bar charts like Coloso et al (2008) to show GPP, R and NEP
Areas of greatest uncertainty with method: reaeration and mixing depth of respiration.
Stability of layers greatly influenced by wind; compare diffusion rate (Coloso 2008)to advective mixing; Result was that wind, instead of suppressing R, enhanced R by mixing bottom water – contrary to common assumption.
Greater

Ocklawaha River Reservoir Management Effects

Reservoir w/ management drawdowns every 3 years to control nuisance invasive aquatic plants

Effects on WQ – nutrient export, algal blooms, change in hydrologic regime – manifested in low DO

Challenges to productivity calculations – tide causing oscillating velocity for reaeration



- Nitrogen enrichment effects on primary producer structure and function (Cohen and Heffernon)
- Continuous C and N metabolism – integrative measure of combined autotroph and heterotroph productivity
- Methods widely attributed to Odum (1957)
- Approaches to parameterization
  - Mechanistic – Explicity calculate flux, reaeration, underwater light, etc.
  - Empirical – Use data as integrator, constrainer of aggregate processes

- Estimates of oxygen reaeration will use published relationships with flow velocity where the nighttime regression (Owens 1973) or peak DO lag (Chapra and DiToro 1992) techniques cannot be validated.

Table 1. Summary of metabolism variables, their associated symbols, and units.

Variable	Symbol	Units
Gross Primary Production	GPP	g O_2 m^{-2} d^{-1}
Net Primary Production	NPP = 0.1875 * GPP	mol C m^{-2} d^{-1}
Ecosystem Respiration	R_E	g O_2 m^{-2} d^{-1}
Net Ecosystem Production	NEP = GPP - R_E	g O_2 m^{-2} d^{-1}
Production:Respiration	P:R	unitless
Autotroph N assimilation	$U_{a,N}$	mg N m^{-2} d^{-1}
Denitrification	U_{den}	mg N m^{-2} d^{-1}
Autotrophic P assimilation	$U_{a,P}$	mg P m^{-2} d^{-1}
Abiotic P retention	$U_{geo,P}$	mg p m^{-2} d^{-1}
Ecosystem stoichiometry*	NPP:$U_{a,N}$:$U_{a,P}$	unitless

* - Note that for ecosystem metabolism stoichiometry, the mass flux of autotroph assimilation of P and N is converted to a molar basis using the atomic mass.