FerryMon: Highlights from a decade of intensive Ferry-based monitoring of the Pamlico Sound system
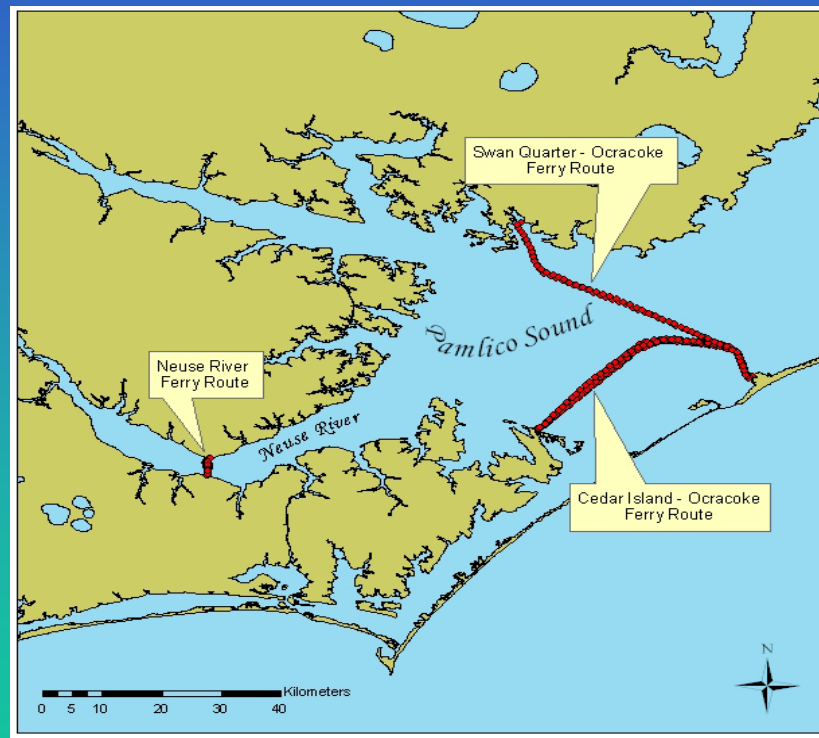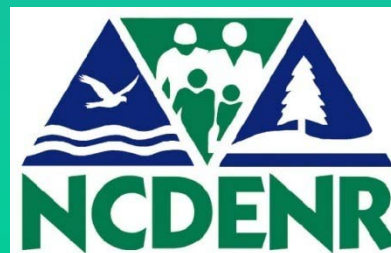
www.ferrymon.org

FerryMon
UNC-CH / DUKE / NCDENR / NCDOT

WATERS NETWORK

Thanks to:
Tim Boynton, Jeremy Braddy,
Rodney Guajardo, Alan Joyner,
Pam Wyrick, Betsy Abare

Swan Quarter - Ocracoke
Ferry Route

Pamlico Sound

Neuse River
Ferry Route

Neuse River

Cedar Island - Ocracoke
Ferry Route

Kilometers
0   5 10   20   30   40

N

NSF

This research is funded by
U.S. EPA - Science To Achieve
Results (STAR) Program
Grant # **82667701**

NCDENR

Sea Grant
North Carolina

The Pamlico Sound System

- Second largest estuary in US

- Most important US SE fisheries nursery

- Drains much of eastern NC and southern VA

- >40 years of Ag and urban expansion accompanied by enhanced N and P loading

- Lagoonal, long residence time (~ 1 Yr), susceptible to eutrophication

- Site of increasing frequency of hurricanes and flooding

The Guts of FerryMon

YSI 6600
Date/Time
In vivo Chl *a*
Salinity
Temperature
Turbidity
pH
DO

ISCO Sampler
Date/Time
In situ Chl *a*
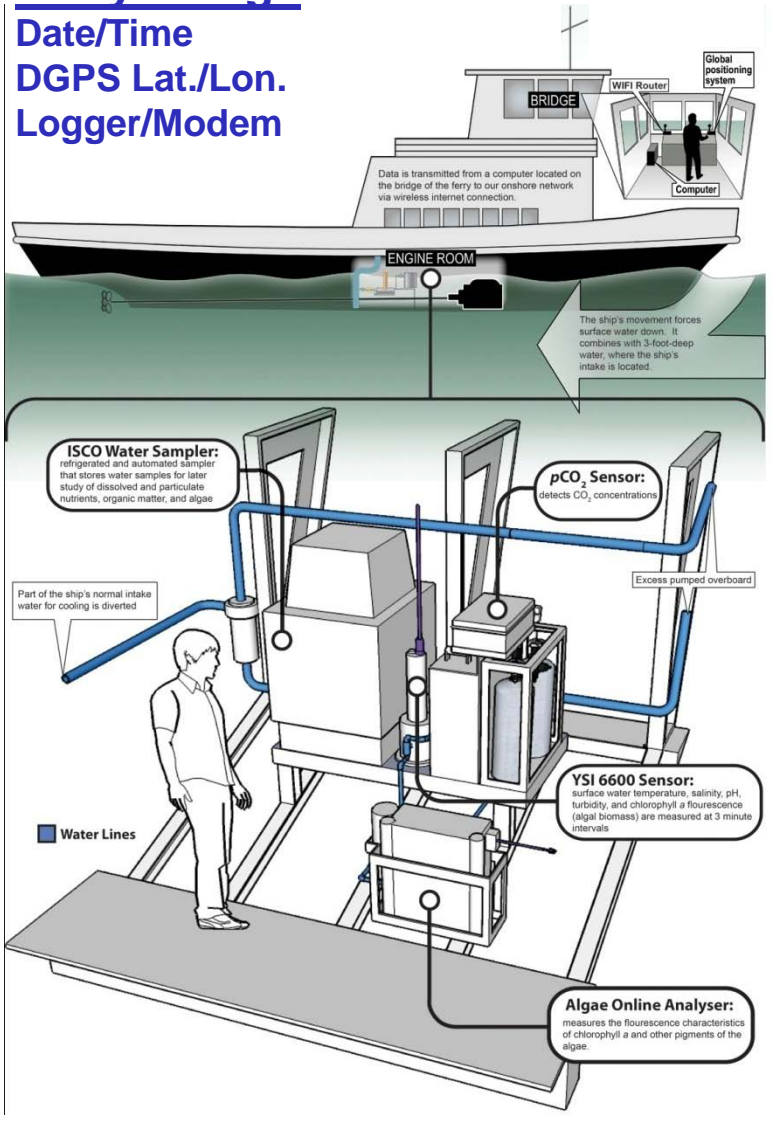Diagnostic Pigments
Nutrients
Pathogens

Ferry Bridge
Date/Time
DGPS Lat./Lon.
Logger/Modem

BRIDGE

WIFI Router

Global positioning system

Computer

Data is transmitted from a computer located on the bridge of the ferry to our onshore network via wireless internet connection.

ENGINE ROOM

The ship's movement forces surface water down. It combines with 3-foot-deep water, where the ship's intake is located.

ISCO Water Sampler: refrigerated and automated sampler that stores water samples for later study of dissolved and particulate nutrients, organic matter, and algae.

pCO₂ Sensor: detects CO₂ concentrations

Part of the ship's normal intake water for cooling is diverted

Excess pumped overboard

YSI 6600 Sensor: surface water temperature, salinity, pH, turbidity, and chlorophyll *a* flourescence (algal biomass) are measured at 3 minute intervals

Water Lines

Algae Online Analyser: measures the flourescence characteristics of chlorophyll a and other pigments of the algae.

Data
Sent via WiFi to
Duke/UNC-IMS
Marine Labs
QA/QC'ed at IMS
Stored in Microsoft
Access Database

pCO$_2$
Date/Time
Gas Equilibrator
Licor CO$_2$ Analyzer
Seabird CTD
Automated
Calibration

FerryMon Products/ Applications

➢ Provide baseline of multiple WQ indicators for Pamlico Sound

➢ Assess the Chl-a standard for the Neuse TMDL

➢ Determine human & climatic drivers of WQ

➢ Determine patterns of WQ variability

➢ Provide data for WQ & observational data models

➢ Provide ground truthing for remote sensing

➢ Provide infrastructure for complementary instrumentation

➢ Enhance public awareness of water quality issues

>80% of Primary Production is Phytoplankton Mediated
Phytoplankton Community Responses are Key to Trophic/Biogeochemical Changes

ModMon: Since 1994
www.unc.edu/ims/neuse/modmon

FerryMon: Since 2000
www.ferrymon.org
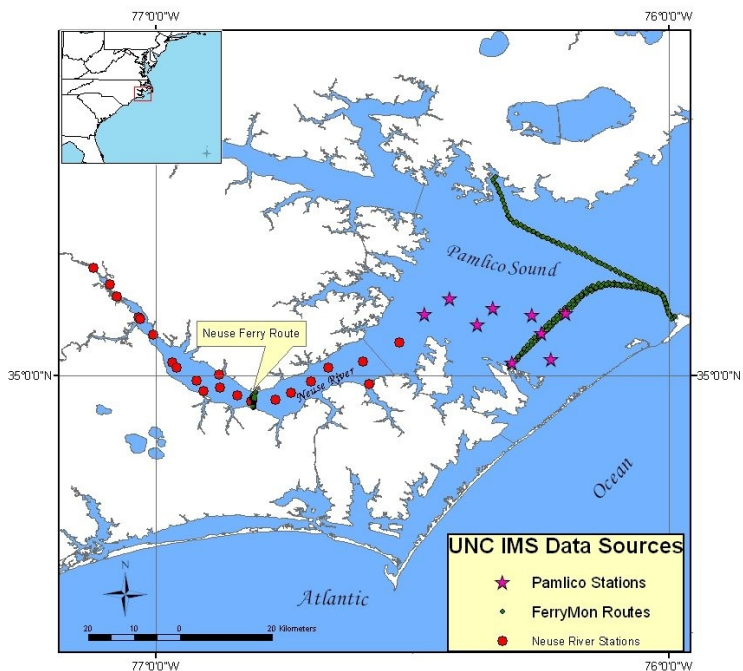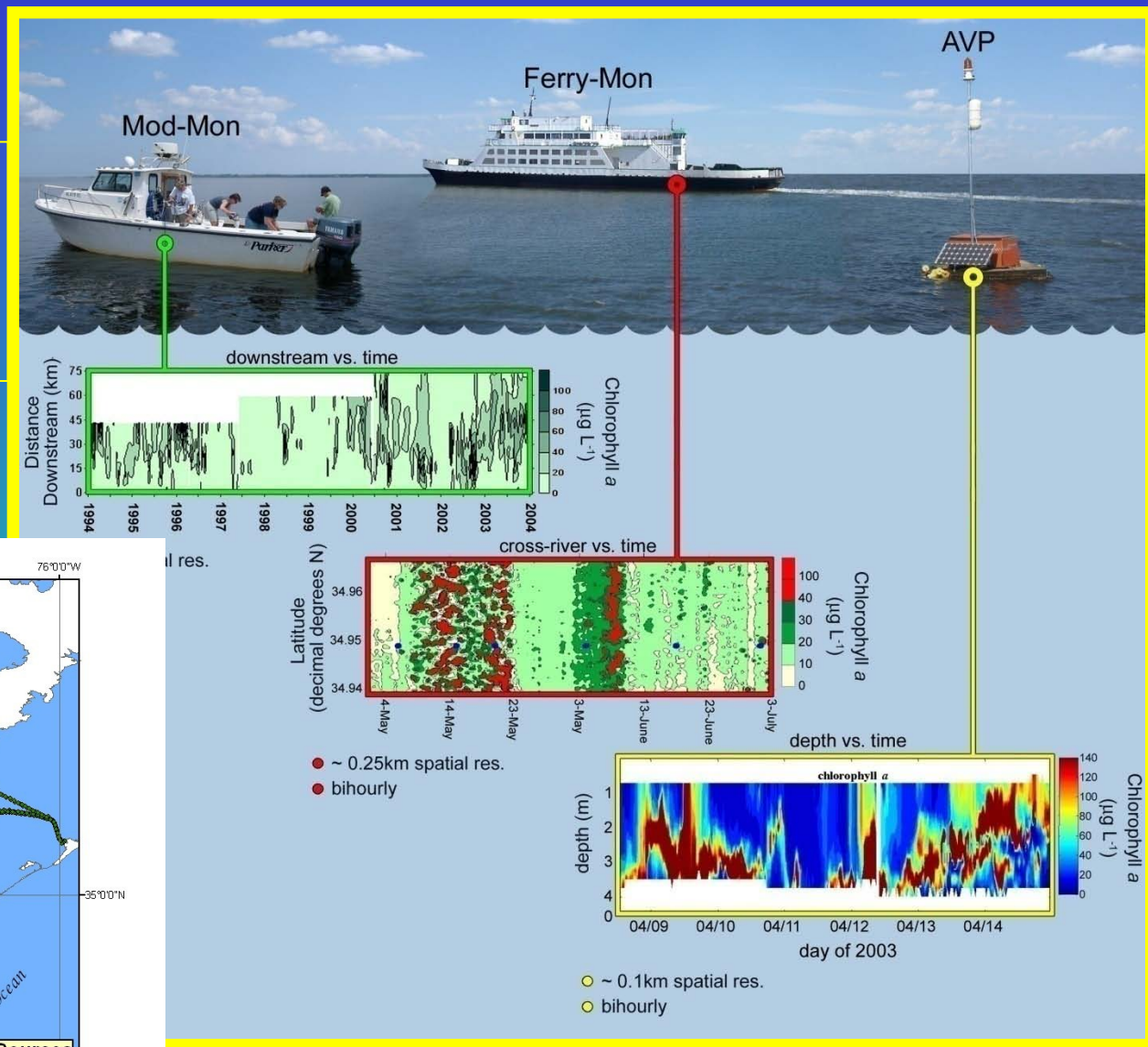
Evaluating the 10/40 Criterion for Chlorophyll *a* in the Neuse River Estuary TMDL Zone

Frequency distribution of chl-a for the middle use support area from 1984- present
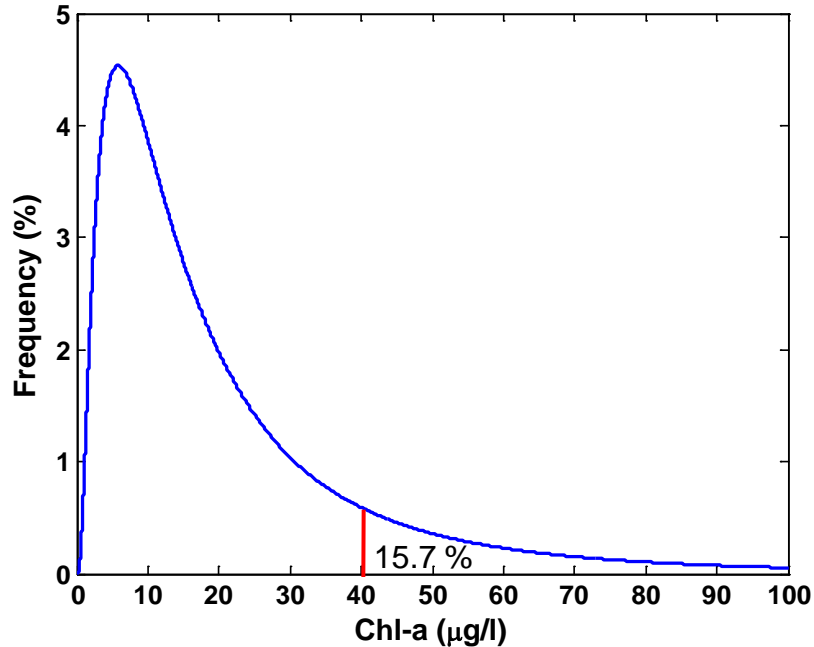
Probability of incorrect compliance determination with different sample sizes
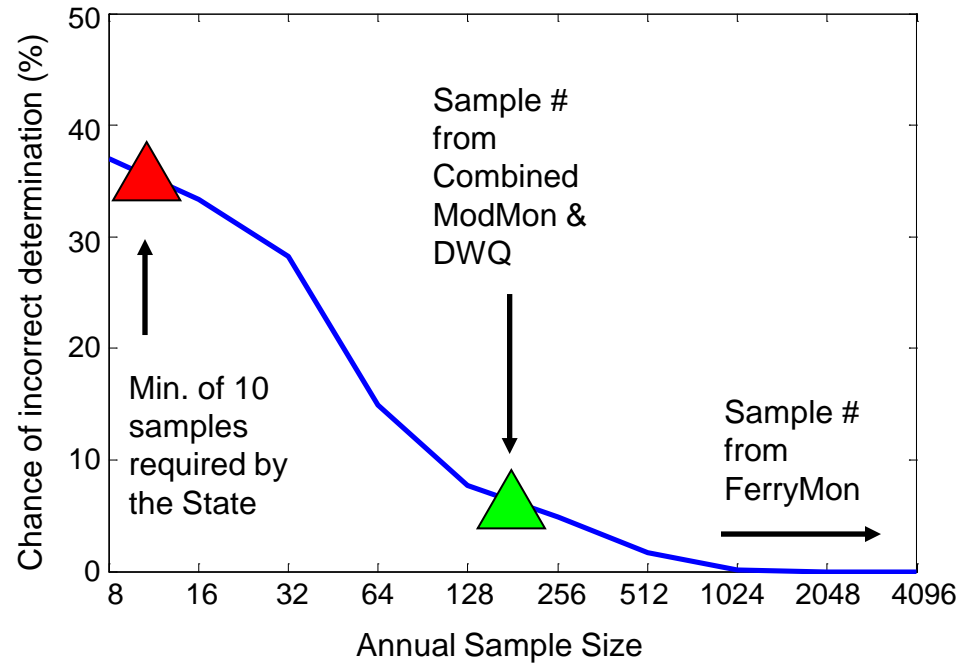
Ability to Accurately and Confidently Determine Compliance Depends On
1) How close the "true" exceedance % is to compliance
2) Number of samples
3) Unbiased sampling

Determining Chlorophyll *a* from *In vivo* Fluorescence

Chl-a = -2.92 + 1.70*fluor + 0.23*sal + 8.7E-4*light*fluor

$R^2 = 0.80$

$p < 10^{-362}$

$N = 1301$
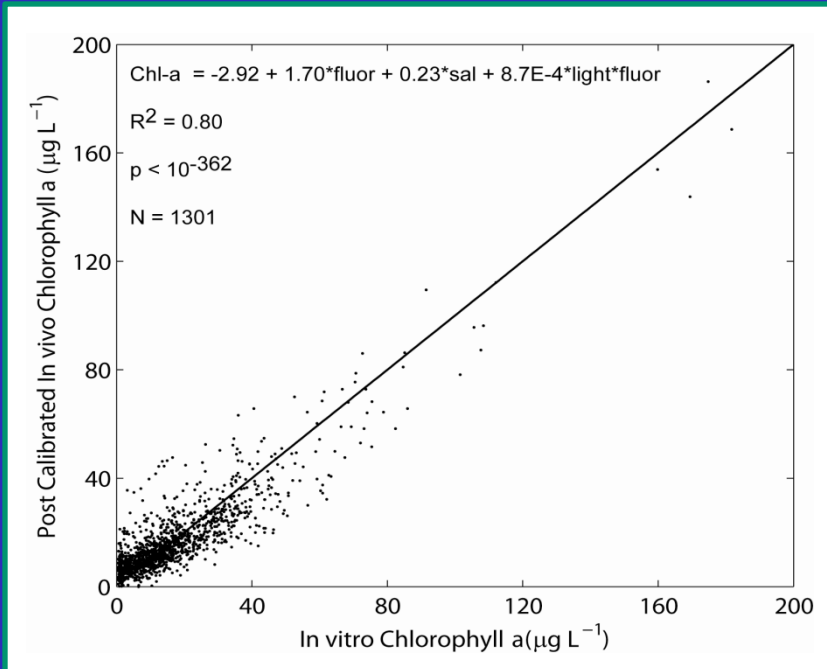
TMDL Compliance for the Bend Use Support Area Based on FerryMon from 2007-2009

Exceedance %	19.4
N	31,965
p_{bd}	$<10^{-300}$

Assessing Spatial Variability:
Cross-Estuary Variability in Phytoplankton Biomass
Does mid-channel (ModMon) sampling lead to biases?
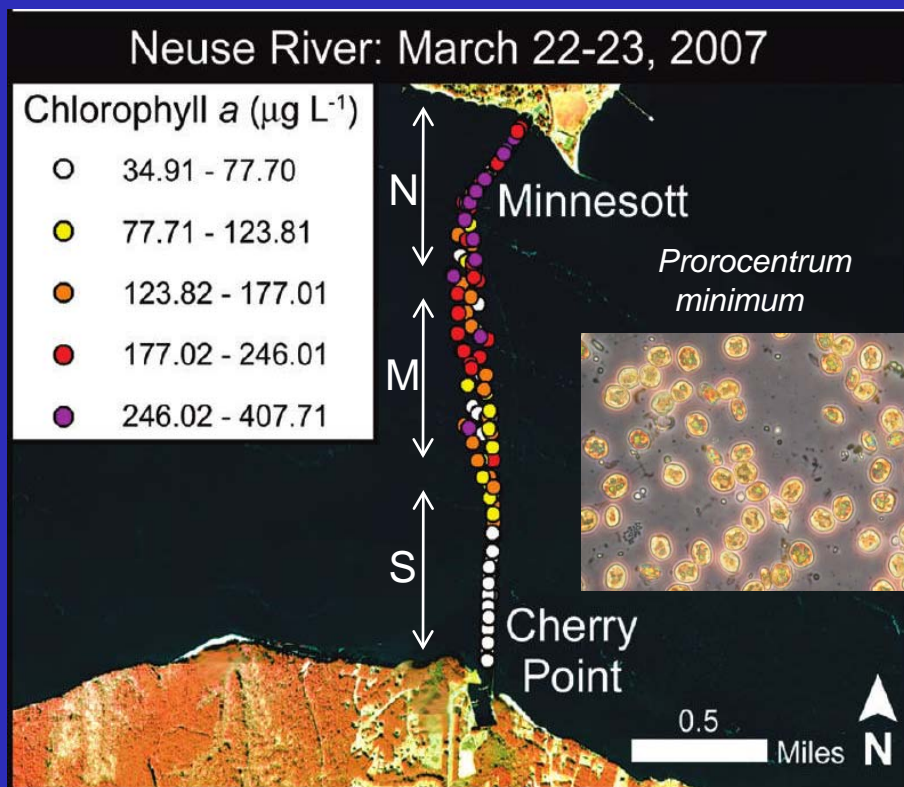
In vivo Fluorescence 2001 to 2010 (N > 400,000)
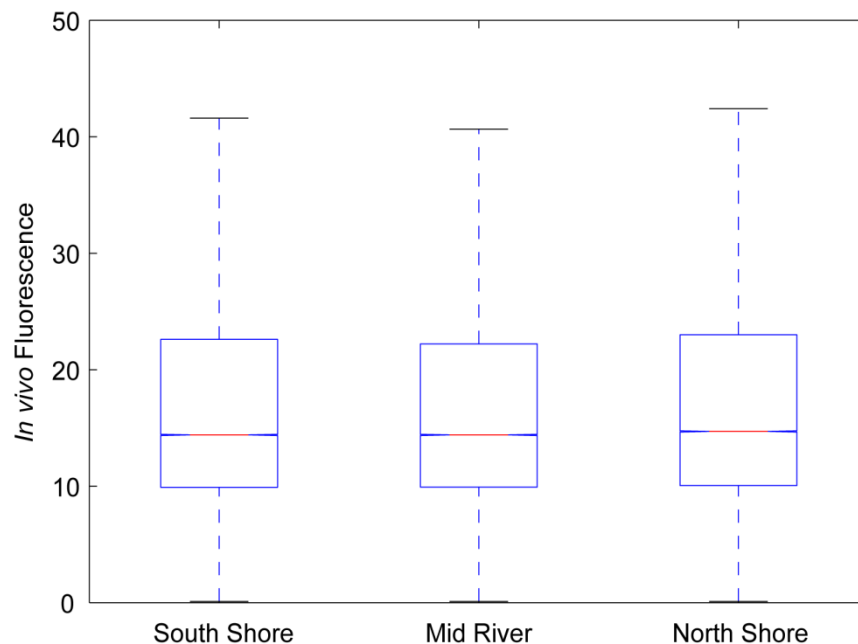
Assessing Effectiveness of Different Temporal Sampling Intervals for Capturing Variability in Chlorophyll *a*

Daily Average *In vivo* Fluorescence, Neuse River Ferry

ModMon & DWQ
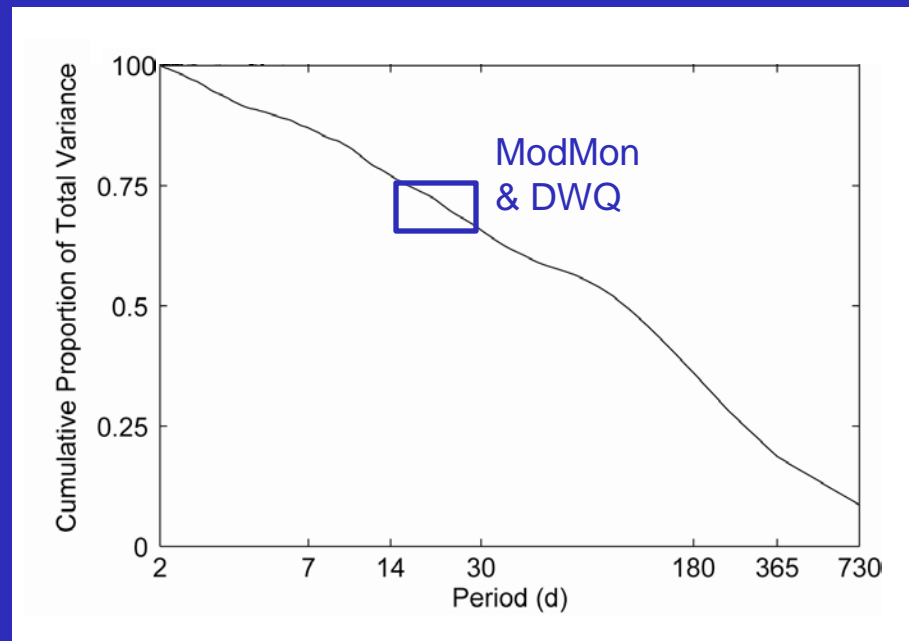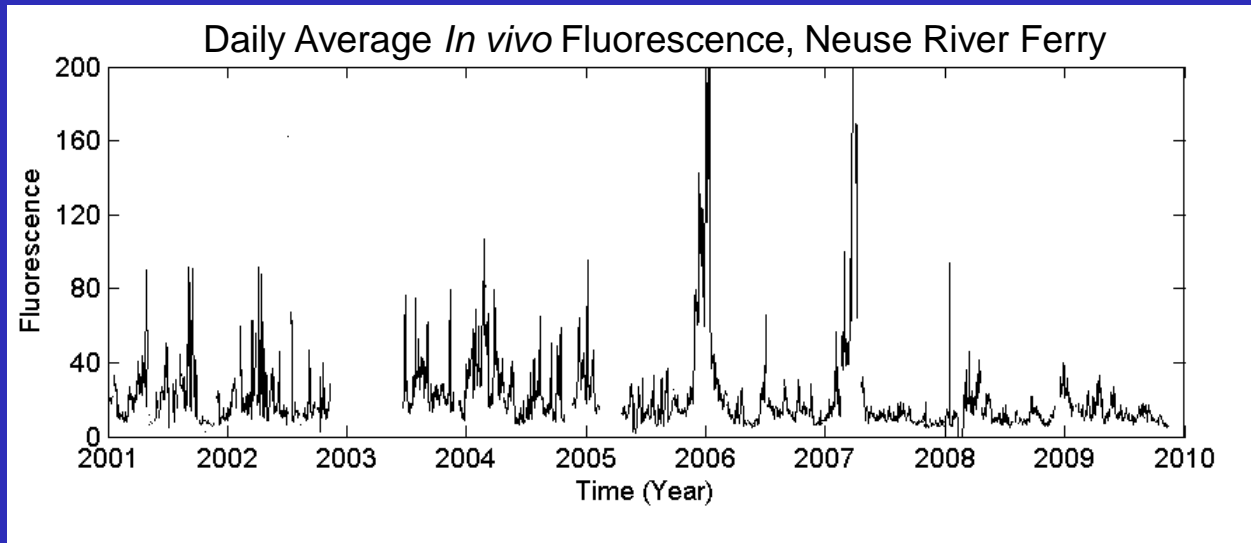
Assessing APES WQ responses
during a period of elevated Hurricane Activity
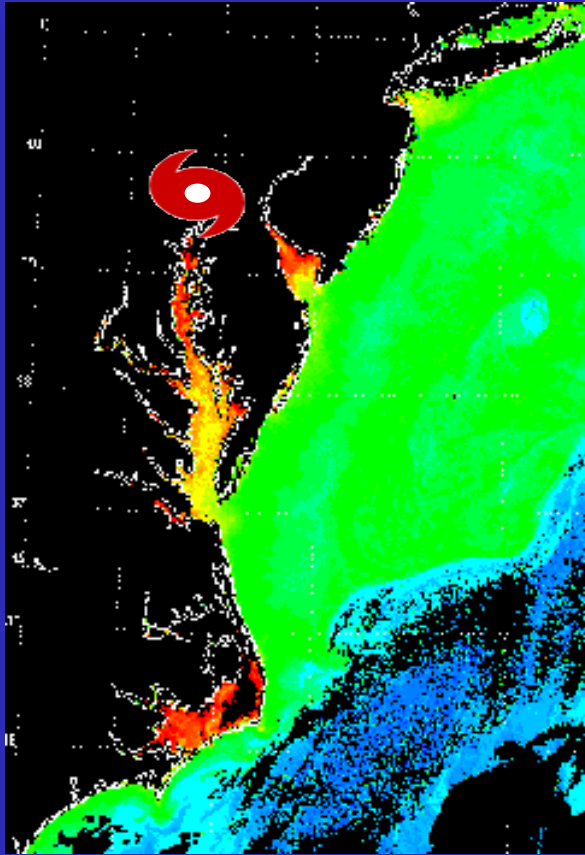
North Atlantic Tropical Storms
10-year running average
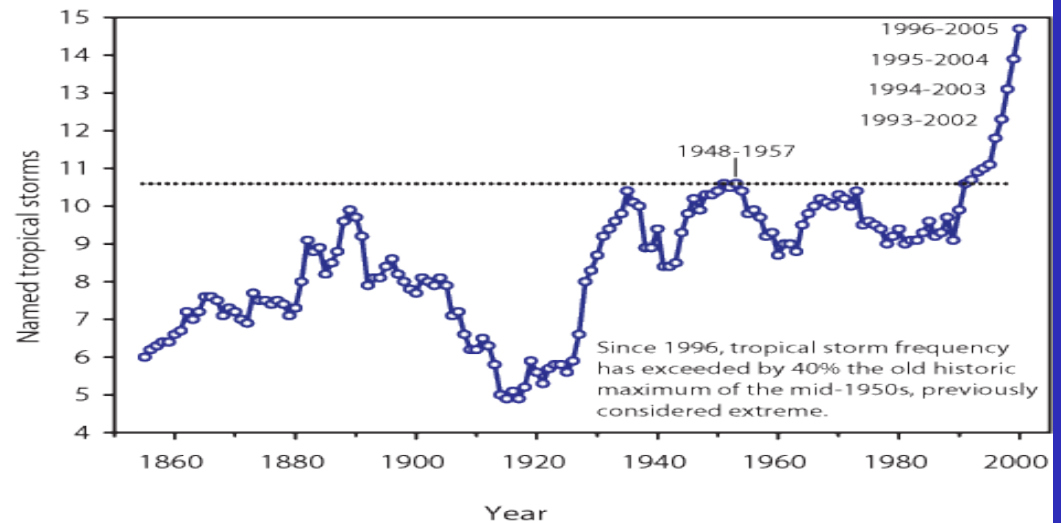
Data Source: National Hurricane Center

Capturing Event Scale Ecosystem Responses
Three Back to Back Storms in 2004
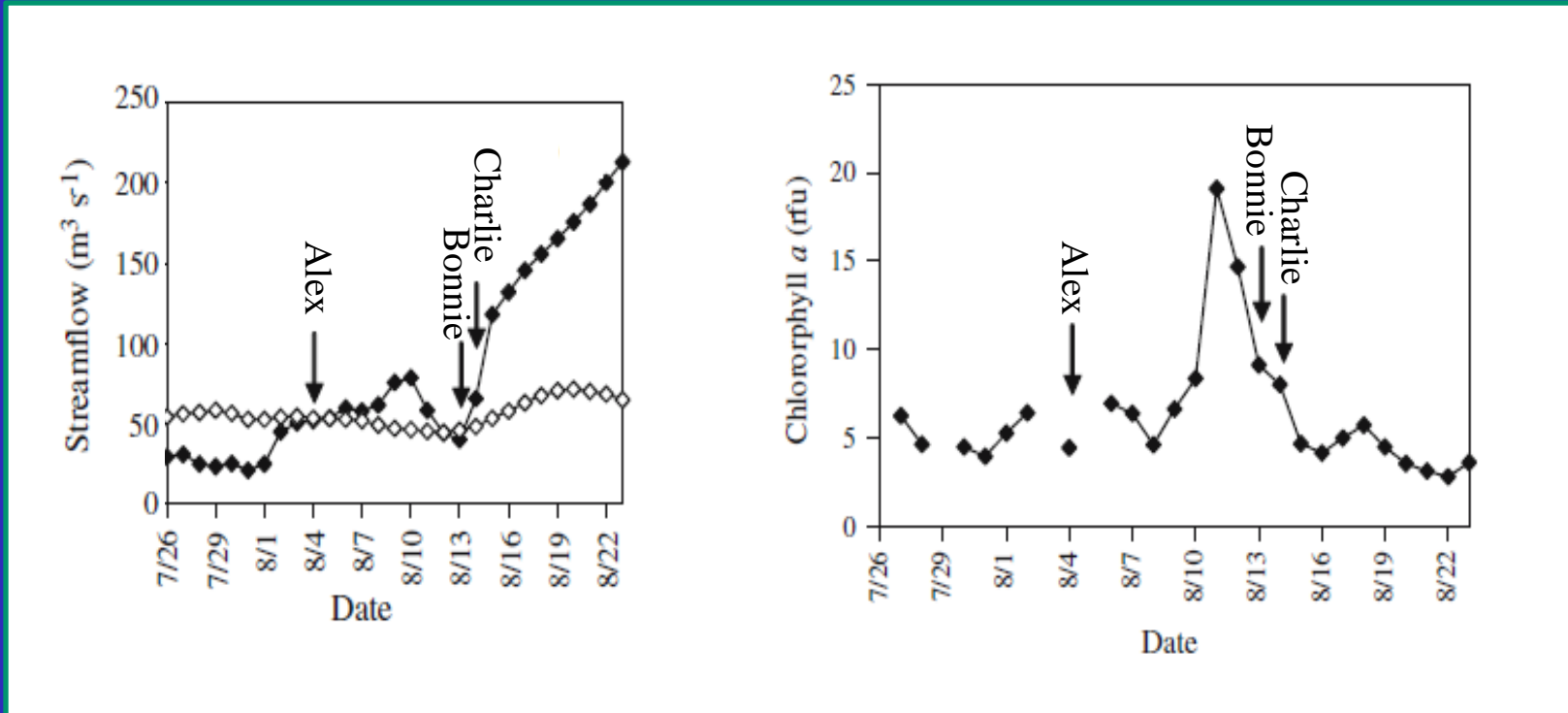
Wetz and Paerl. 2008. Estuaries and Coasts 31:419-429.

Phytoplankton bloom following Hurricane Alex (low rainfall)

Bloom was terminated by flushing from high rainfall storms, Tropical Depression Bonnie and Tropical Storm Charlie

09/08/1999, Before

Sept. 2003: Isabel "creates" a new inlet in the Outer Banks

09/21/2003, After
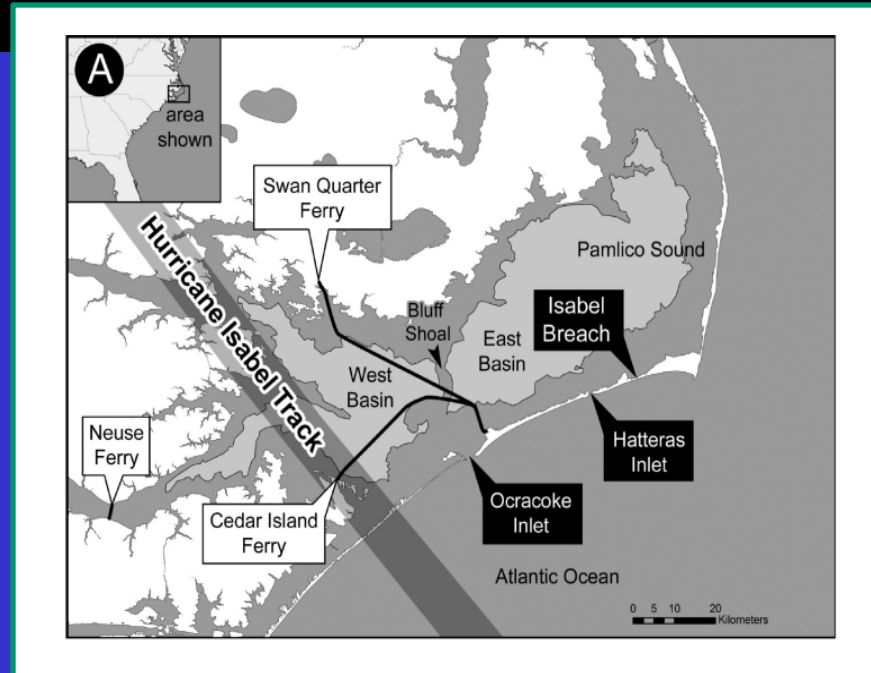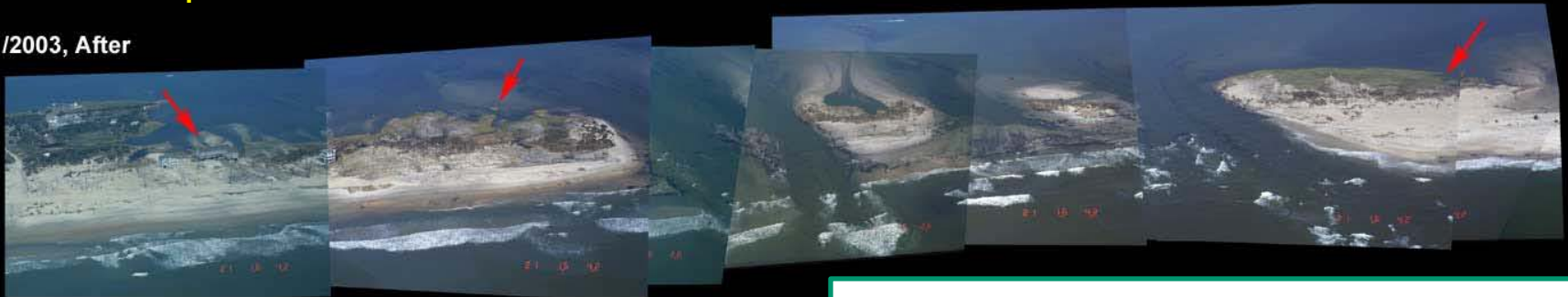
Salinity Patterns in Pamlico Sound Demonstrate Storm Driven Changes in Connectivity to Coastal Ocean

Difference in average weekly salinity between east and west basins

Paerl et al. 2009. Environ. Sci. Technol. 43:7609-7613.
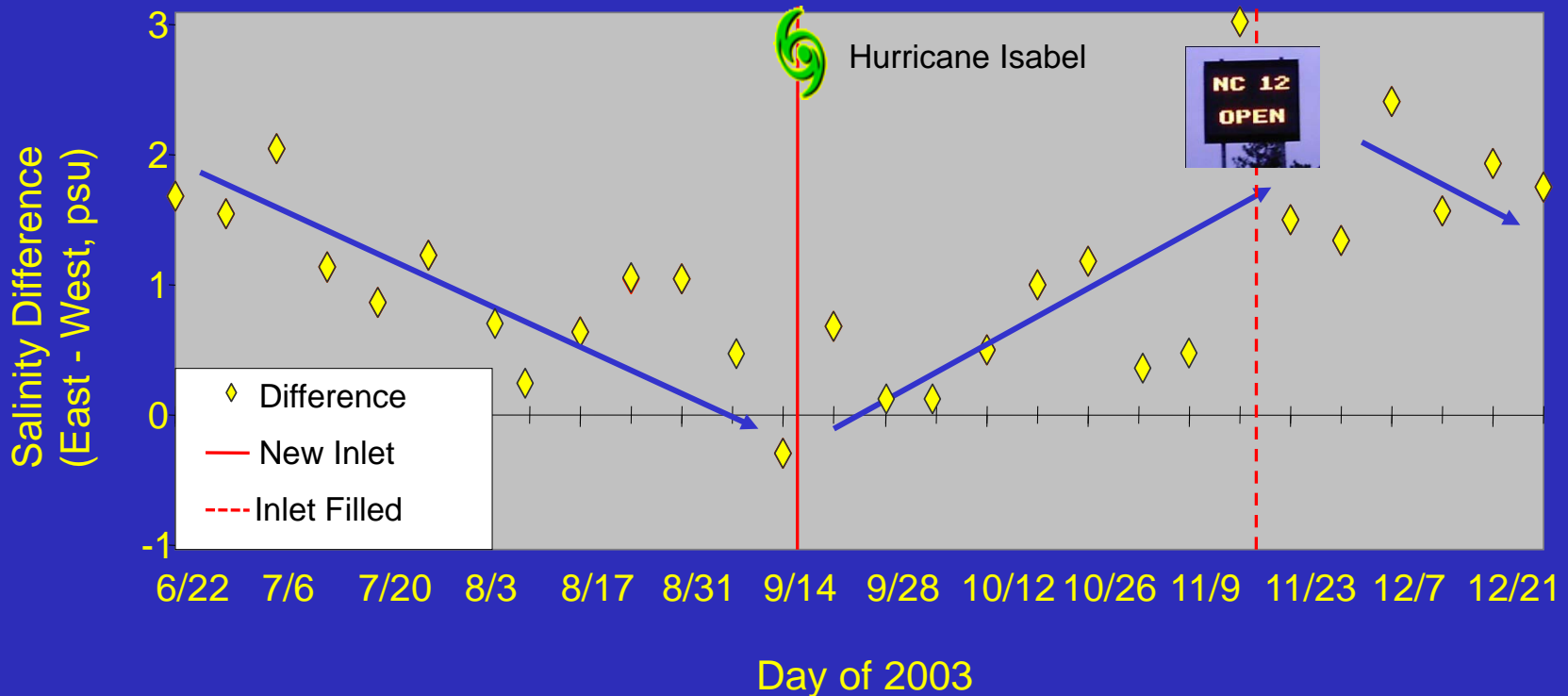
Air-craft Based Remote Sensing

AVIRIS imagery calibrated against ModMon ground truth data in the Neuse R. & Pamlico S. (Lunetta et al 2009)

1) **Demonstrated that MERIS bands can produce good estimates of chl-a and TSS**
2) **But would the relationship hold under different atmospheric, sea state, and water quality conditions?**

$y = 60.2x - 58.6$
$R^2 = 0.98$
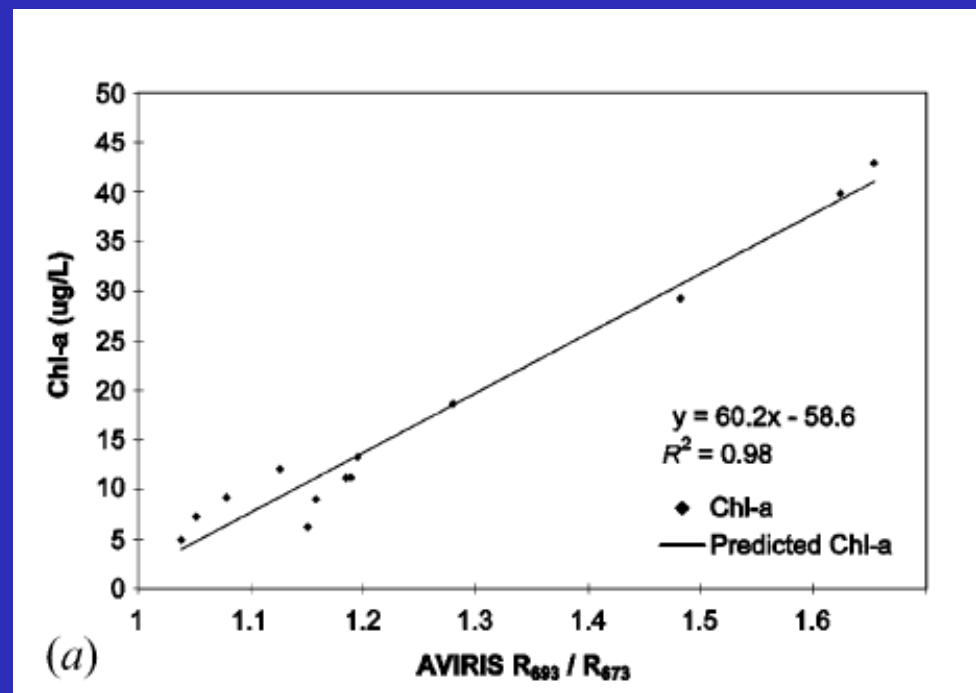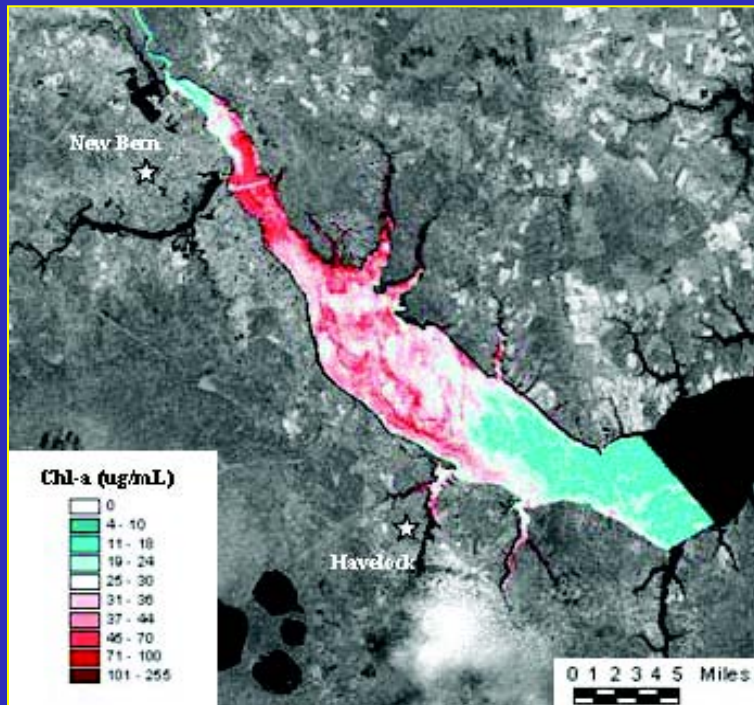
Satellite Based Remote Sensing

FerryMon Ground Truth Data Used To Calibrate/ Validate Algorithms (MERIS Imagery, European Space Administration- Envisat Satellite)
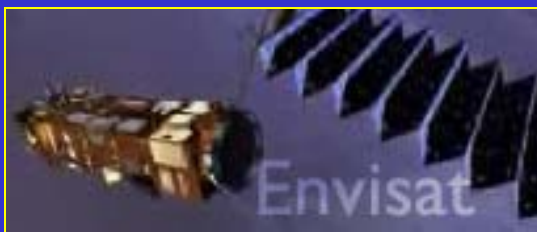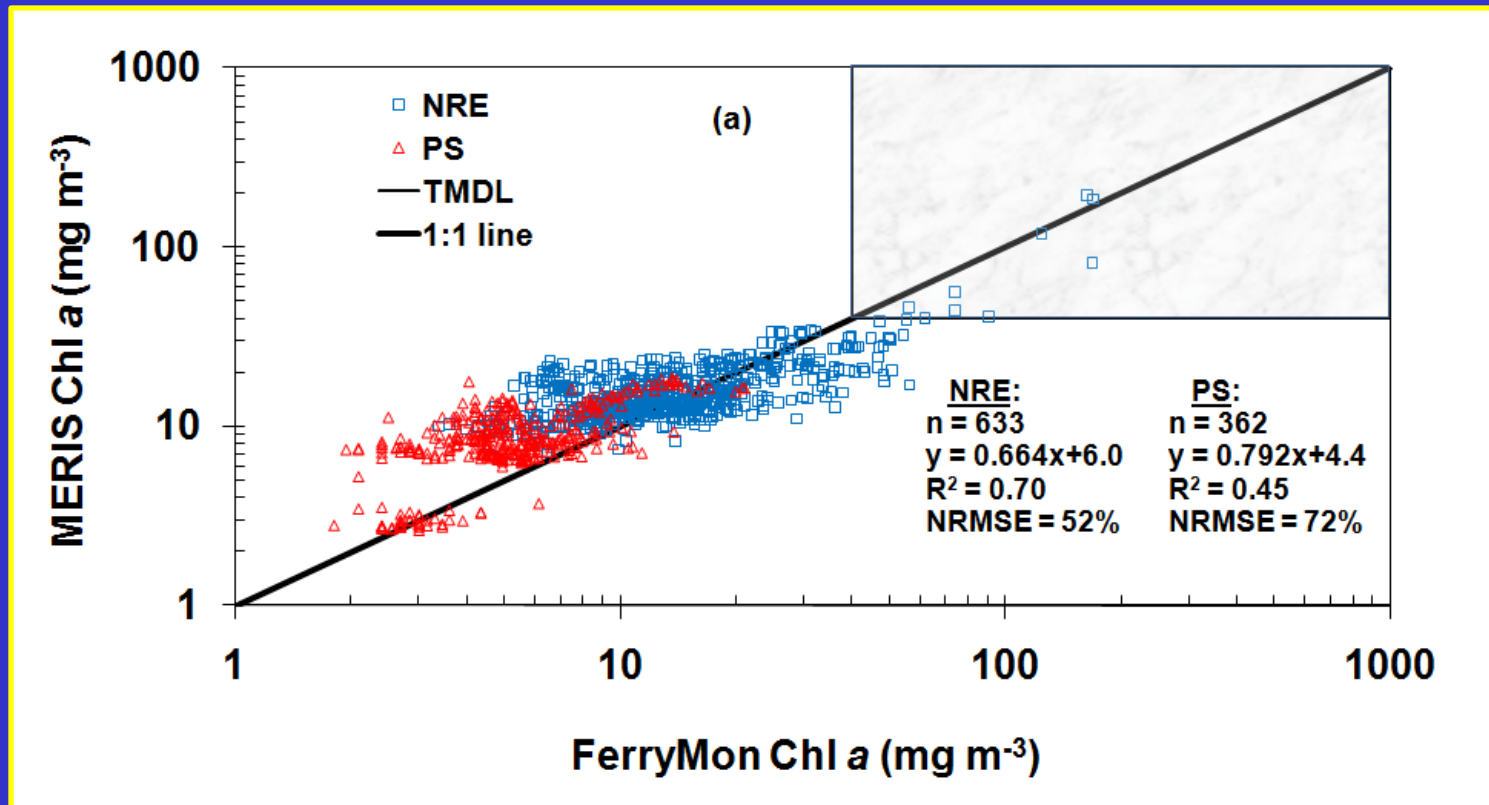
Sokoletsky et al. 2011. Remote Sensing 3:684-707

Filling the "Coastal Zone Gap" for Global C Budgets
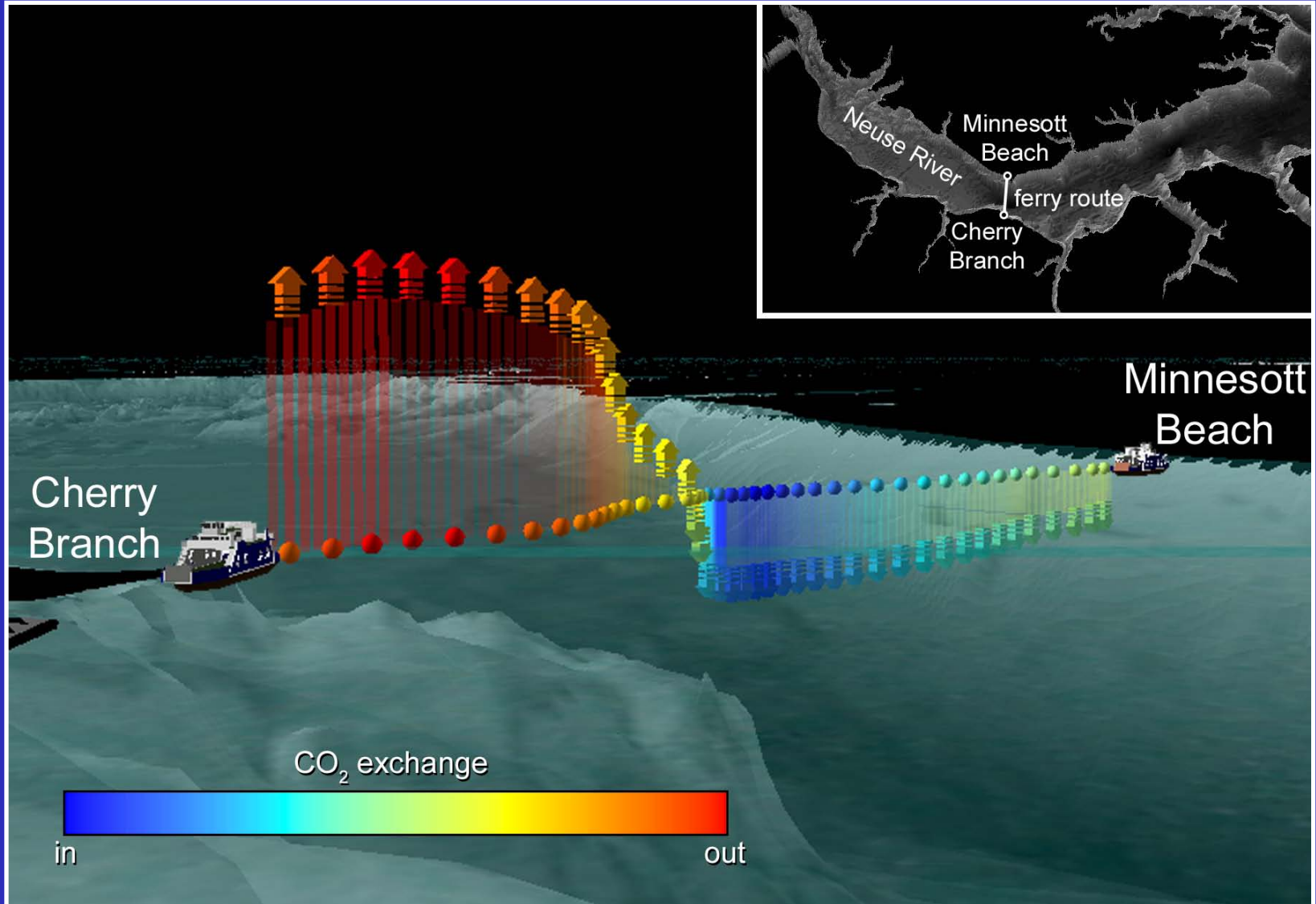
Influence of Phytoplankton Production
Spatial Distribution of pCO_2

Neuse River Estuary, 28 January 2010
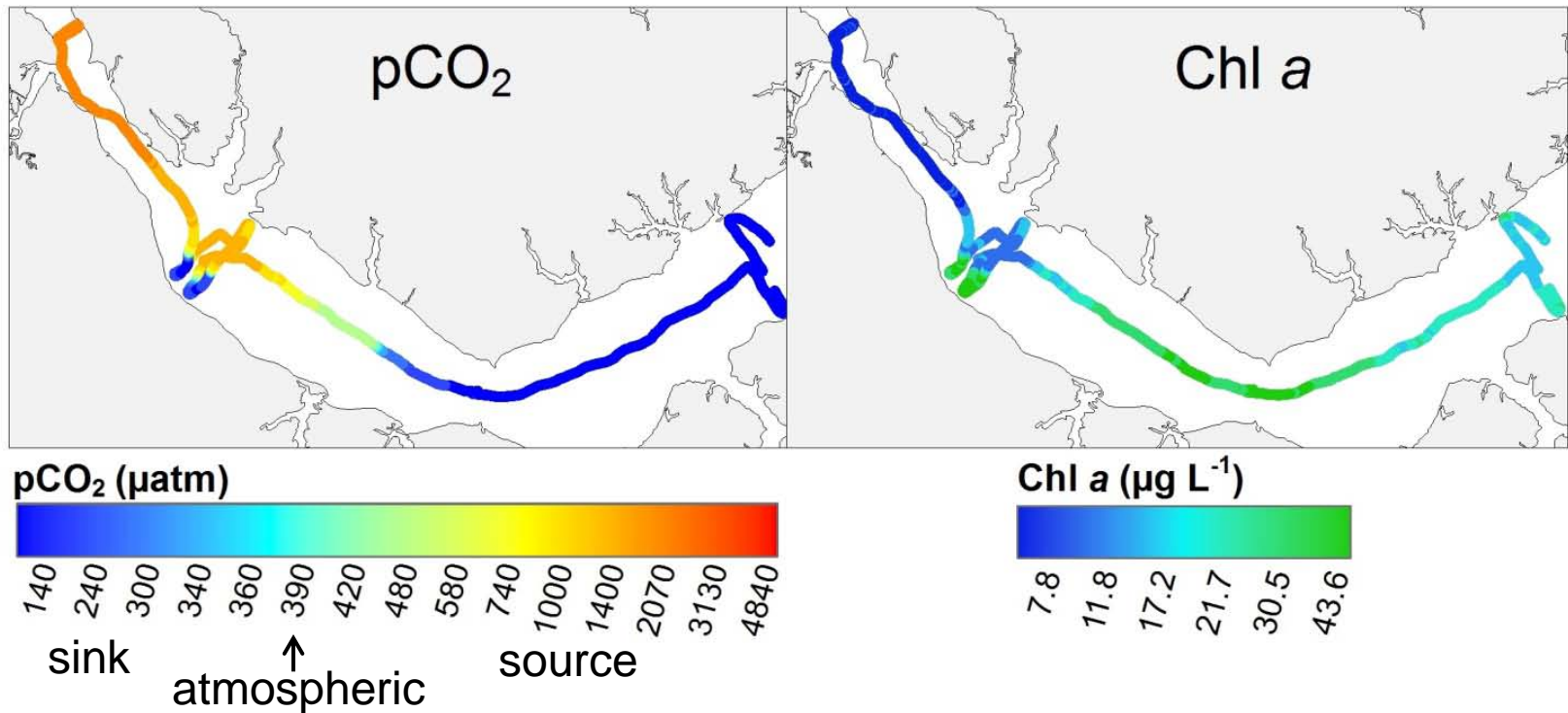
Influence of Phytoplankton Production / Respiration Diel Fluctuations in pCO$_2$ Revealed by FerryMon

Mid-channel pCO$_2$ on 8/14/11

source

atmosphere ~390 μatm

sink

pCO$_2$ (μatm)

Time of Day (h)
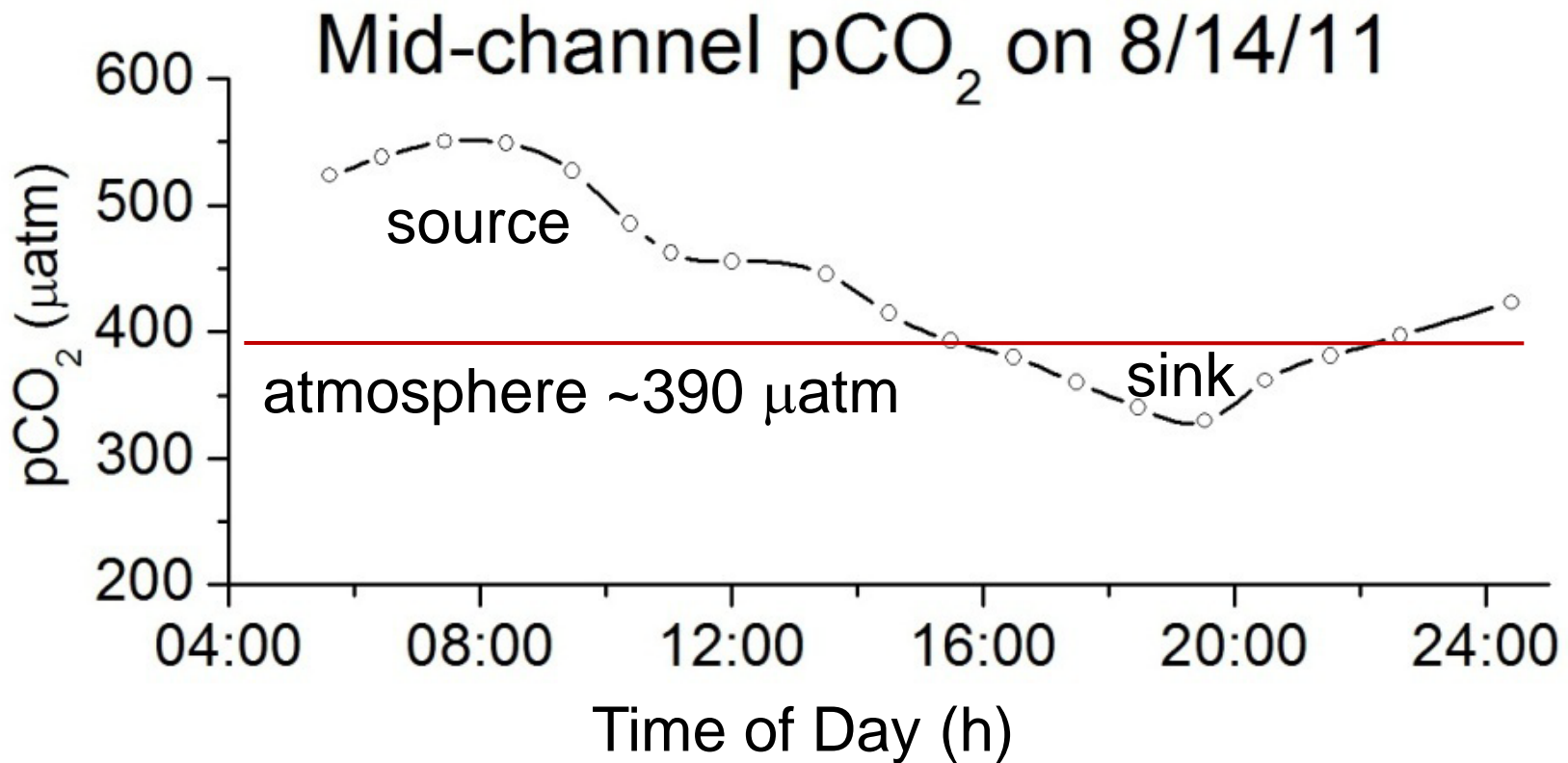
Impact of Hurricane Irene on CO_2 Dynamics in the Neuse River Estuary

Outreach and Education

On the Web

Weekly Summaries

K-12 Lesson Plans

On the Ferries

Educational Poster

Out and About

Maritime Museum Exhibit

FerryMon: A Model for the Nation