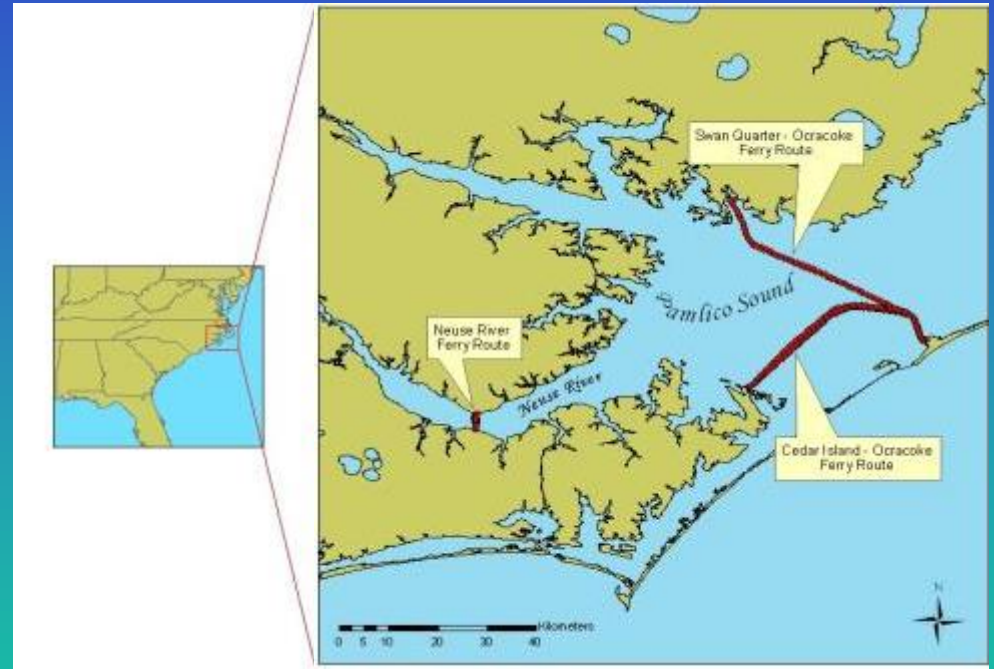


FerryMon: Ferry-based assessment of human and climatically-driven ecological change in the Neuse River-Pamlico Sound Estuarine System, NC, USA

Hans Paerl, Joseph Crosswell, Karen Rossignol, Nathan Hall, Alan Joyner and Ben Peierls
UNC-Chapel Hill, Institute of Marine Sciences, Morehead City, NC, USA



www.ferrymon.org



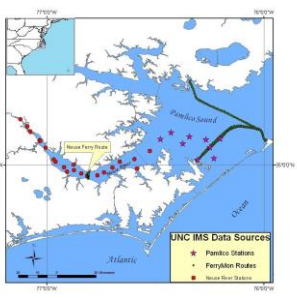
The Albemarle/ Pamlico Sound Estuarine System



- Second largest Estuary in US
- Most important US SE fisheries nursery
 - Drains over half of NC coastal plain
 - >40 years of Ag and urban expansion accompanied by enhanced N and P loading
- Lagoonal, long residence time (~ 1 Yr), susceptible to eutrophication
- Increasing frequency of tropical cyclones (10 in the past 12 years), and flooding



How does FerryMon work?



YSI 6600

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



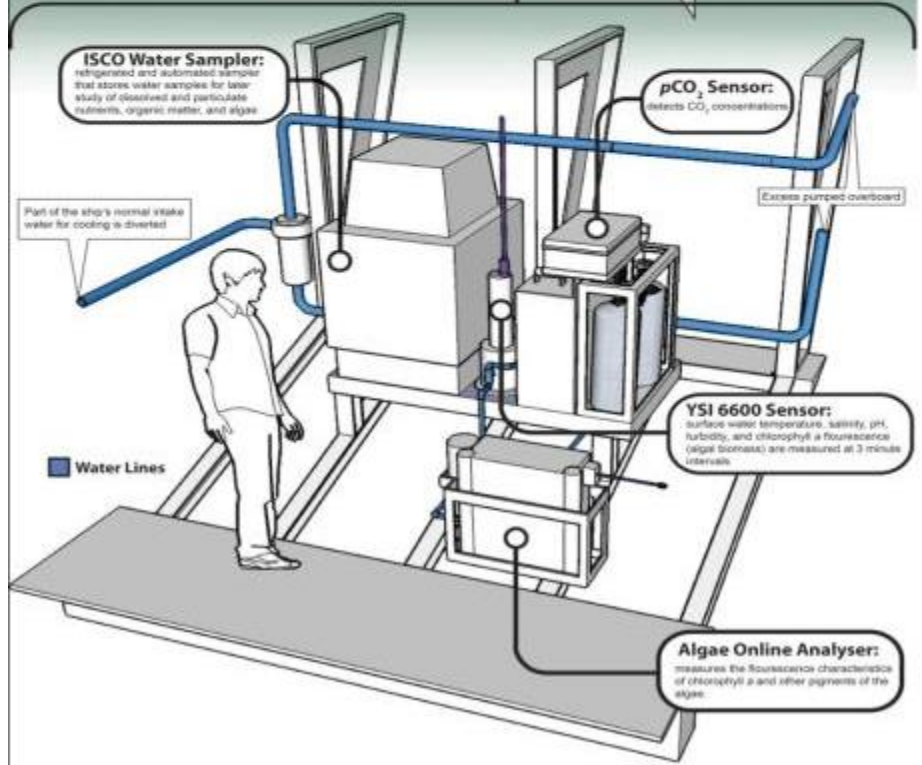
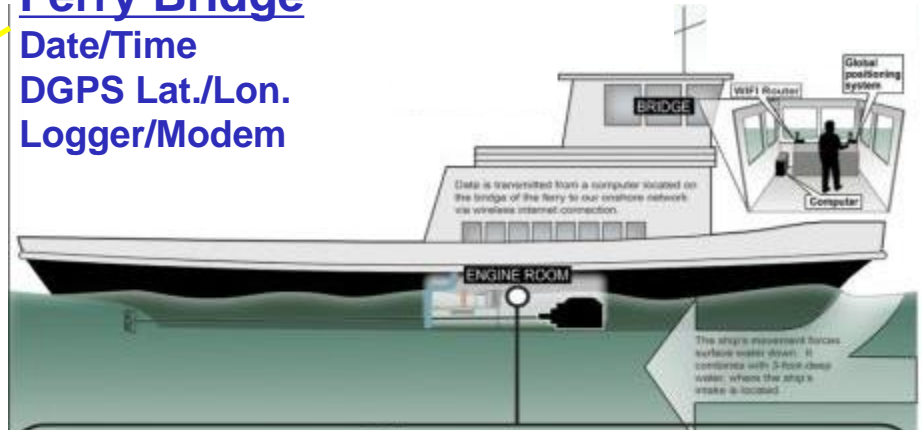
ISCO Sampler

Date/Time
In situ Chlorophyll *a*
Diagnostic Pigments
Nutrients
Pathogens



Ferry Bridge

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



Data

Sent via WiFi to
Duke/UNC-IMS
Marine Labs daily

QA/QC' ed at IMS
Stored in Microsoft
Access Database

Samples

Collected weekly-
monthly

Analyzed at UNC-IMS

Data QA/QC' ed
and stored at IMS



1. Sonde (YSI)

- Chl fluorescence (chl a)
- Dissolved Oxygen (DO)
- pH
- Turbidity

2. TSG (Seabird)

- Salinity (SSS)
- Temp (SST)



3. Equilibrator

- Temp
- Pressure

4. NDIR CO₂ Analyzer (Licor)

- xCO₂

5. Calibration gas standards



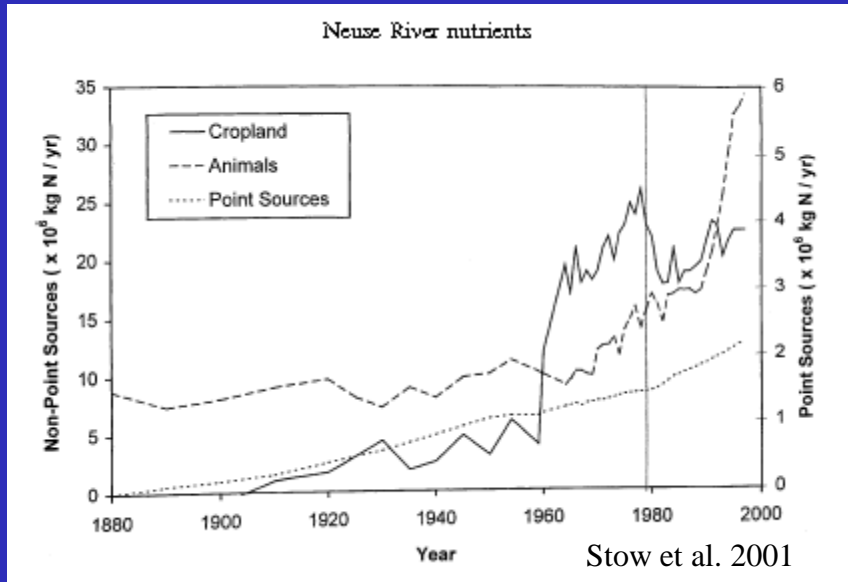
pCO₂

FerryMon Products/ Applications

- Provide baseline of multiple WQ indicators for Pamlico Sound
- Assess compliance with NC & EPA WQ standards
- Determine human & climatic drivers of WQ
- Determine patterns of WQ variability → event scale
- Provide data for WQ & circulation models
- Provide ground-truthing for remote sensing
- Provide for complementary instrumentation, including recent in line pCO₂ measurements
- Enhance public awareness of WQ issues

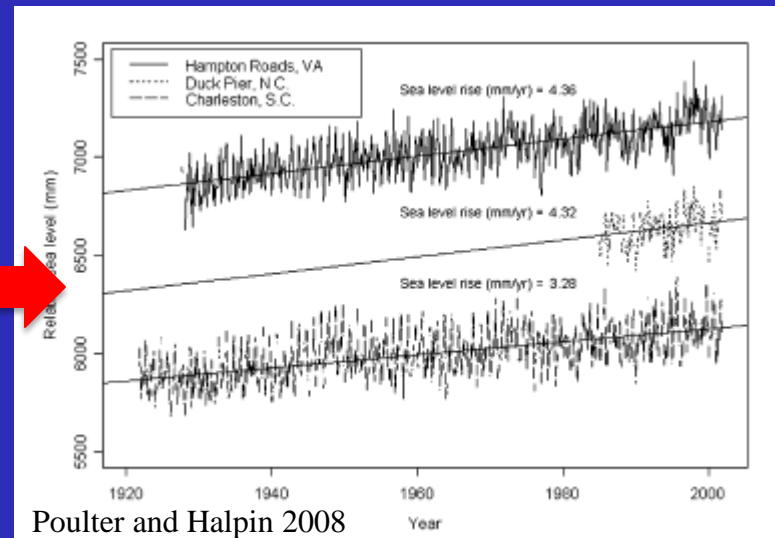
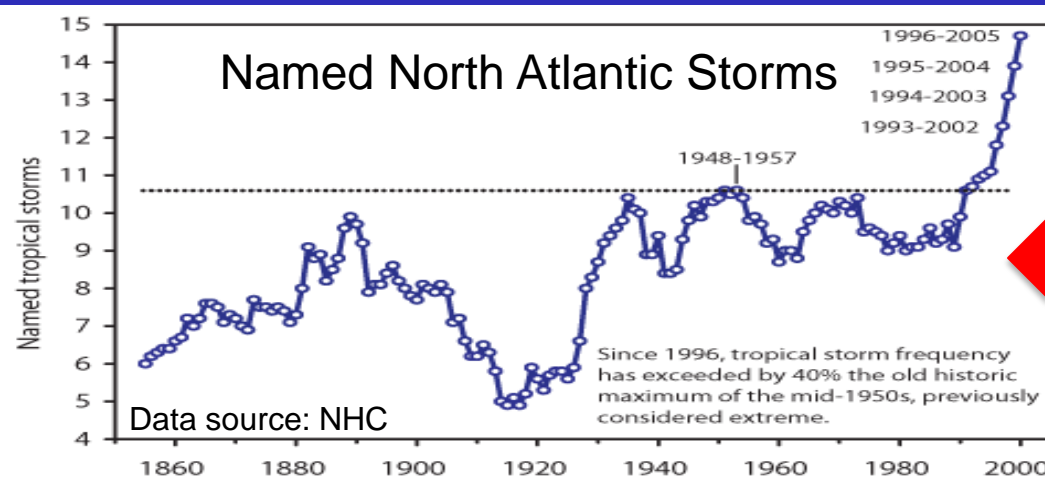
Detecting Synergistic Impacts from Multiple Stressors

Land use and Nutrient Loads

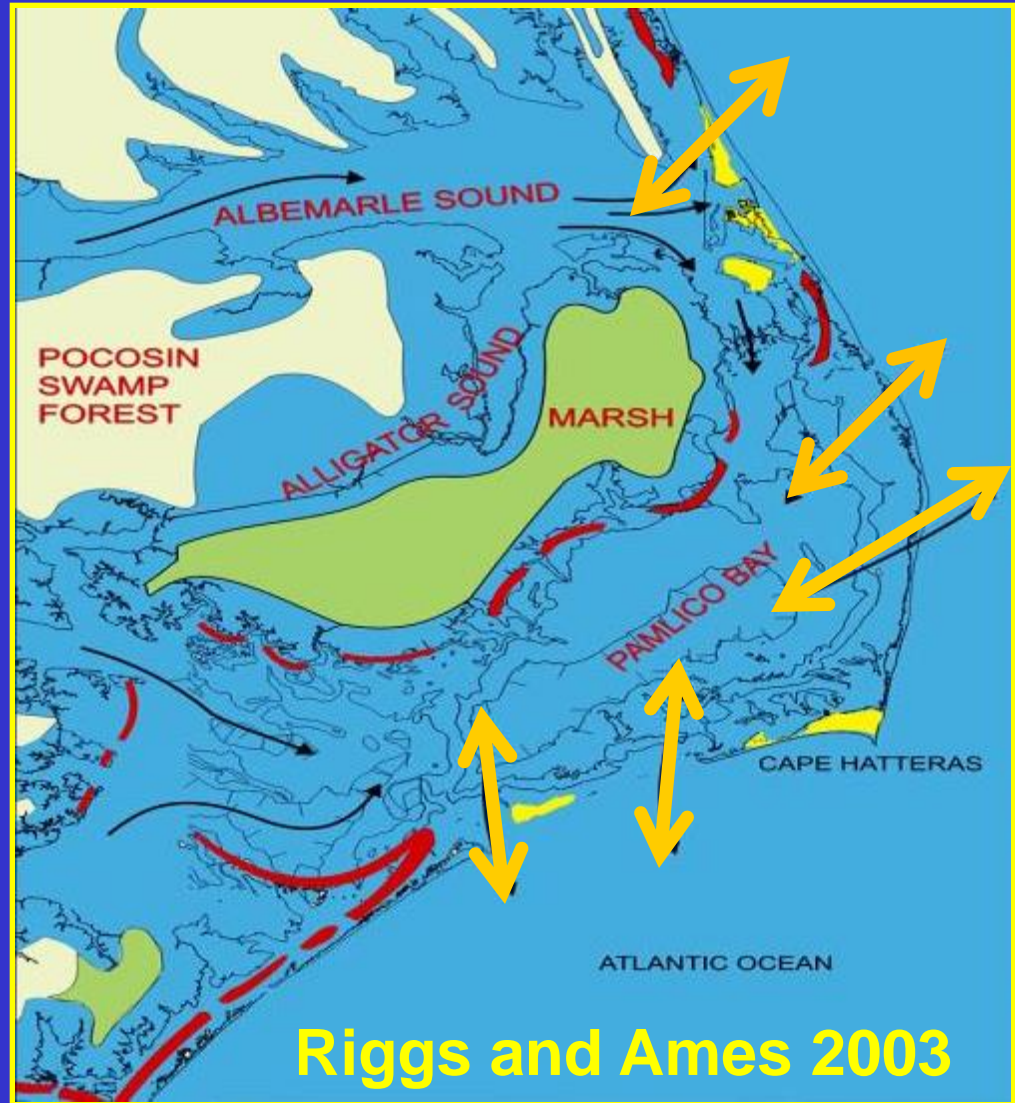


Sea Level Rise & Coastal Erosion

Climate Change & Storms



Now & Later?



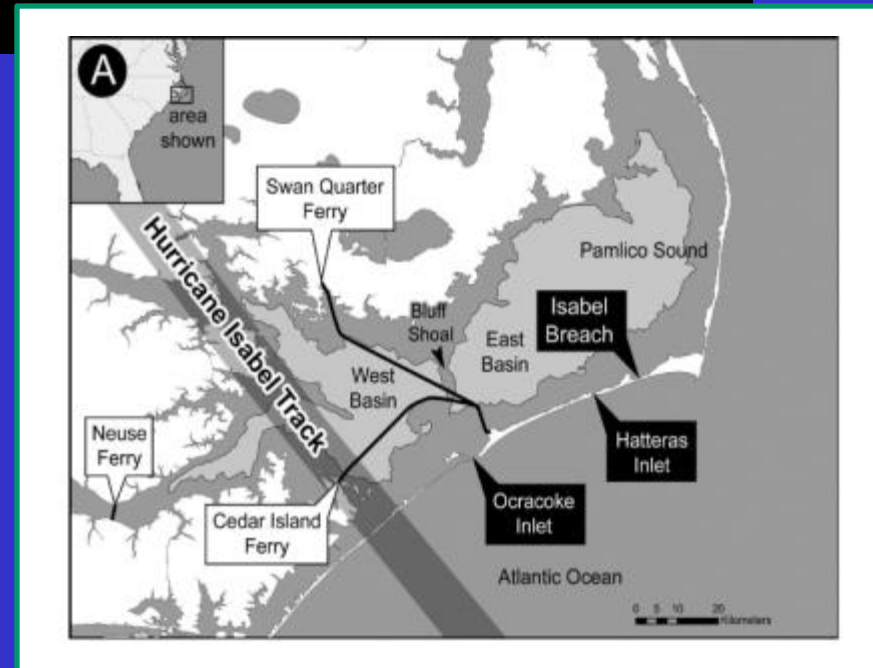
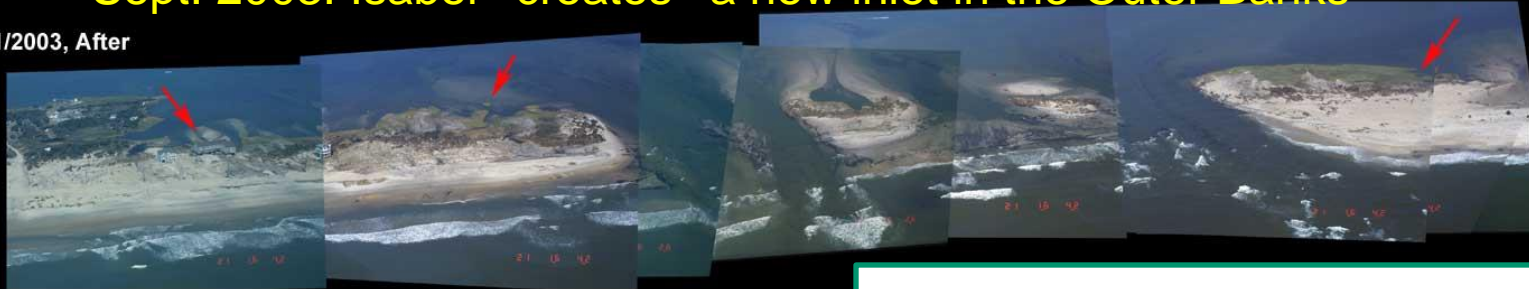
A glimpse of a more "open" Pamlico Sound → Bay

09/08/1999, Before



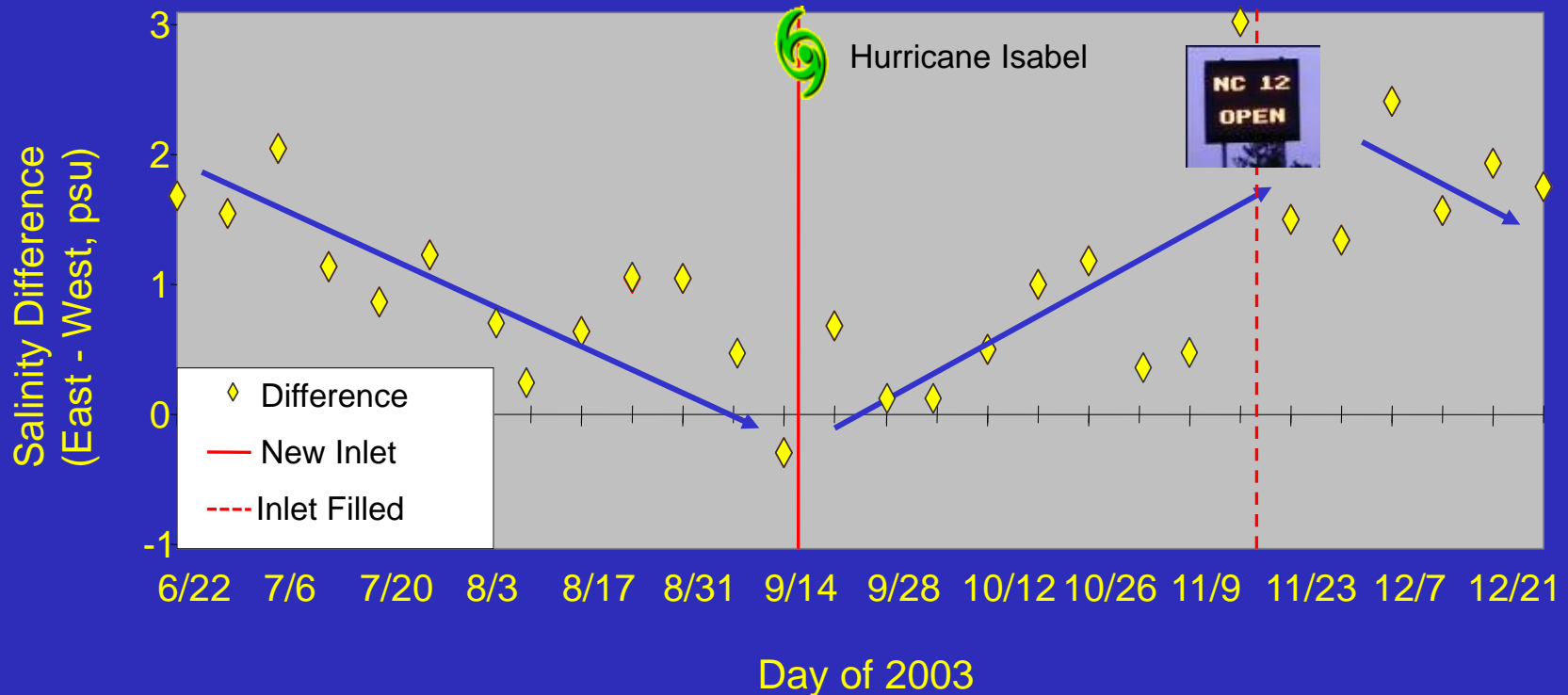
Sept. 2003: Isabel "creates" a new inlet in the Outer Banks

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



How will sea level rise impact the Sound?

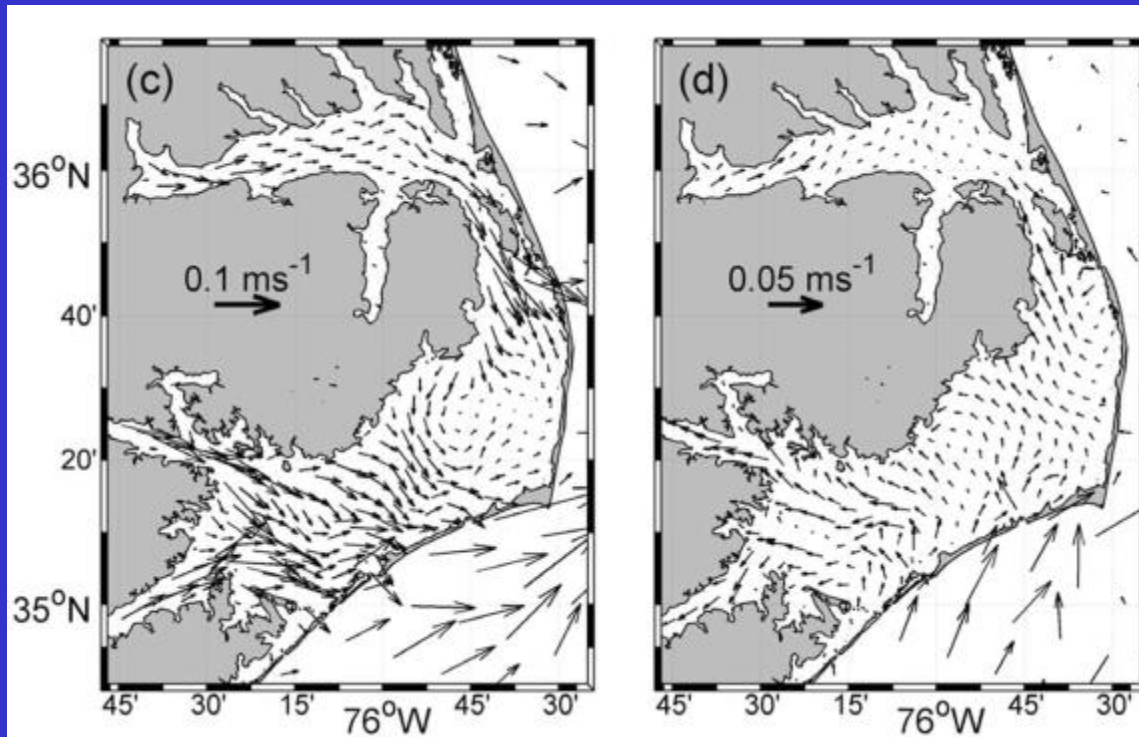
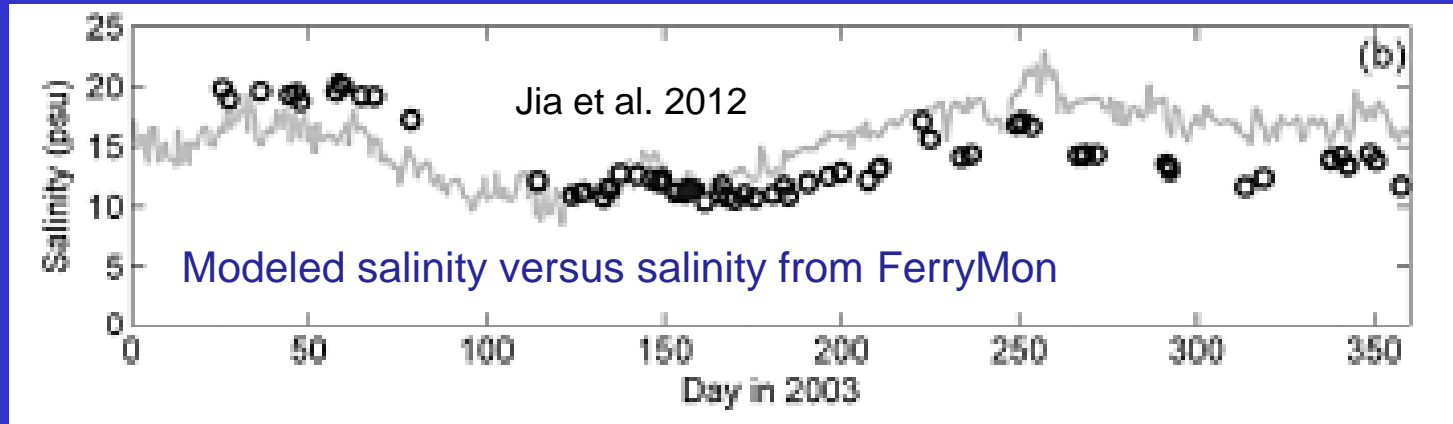
Changes in circulation, flushing, salinity regimes?

Water clarity?

Changes in community structure?

FerryMon provides data to detect &
understand these changes
& inform science based management.

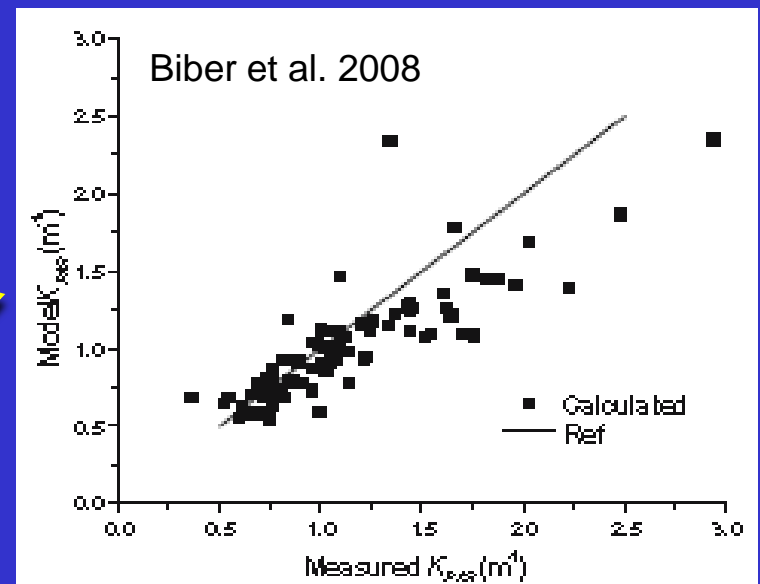
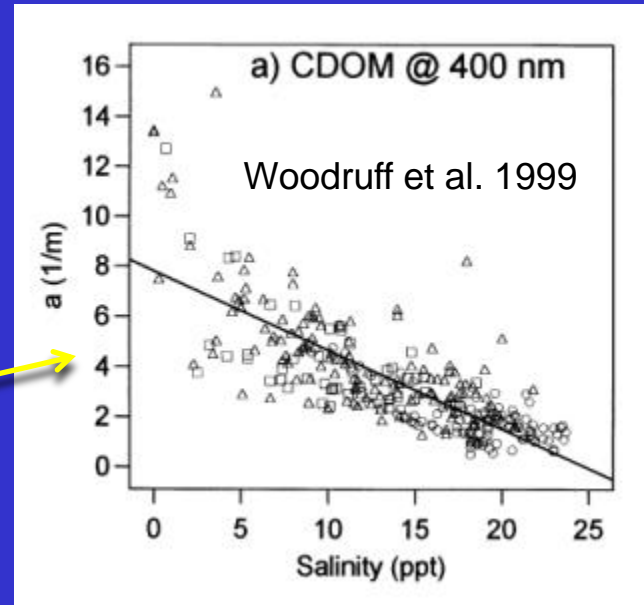
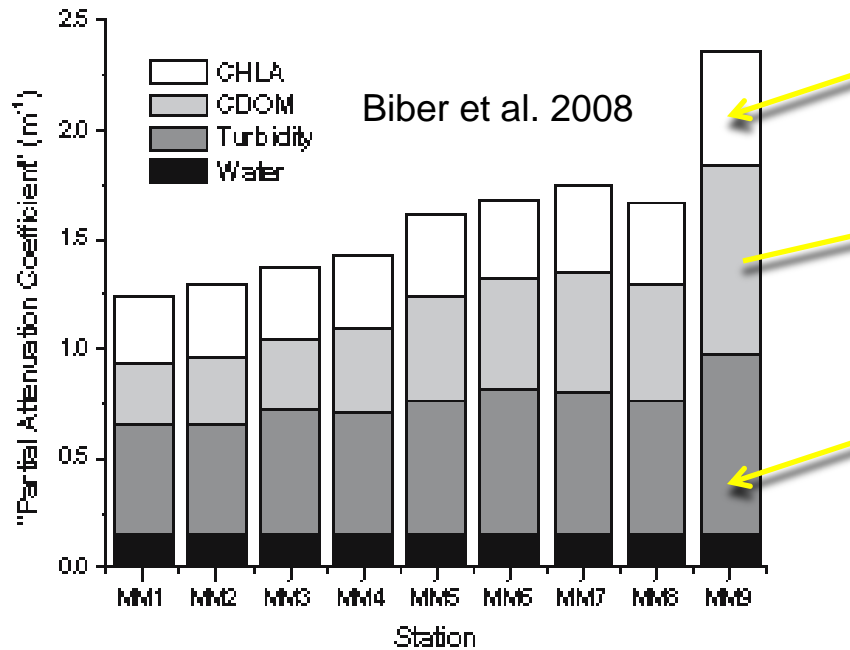
Calibration/ validation of circulation models for Pamlico Sound



Mean circulation patterns

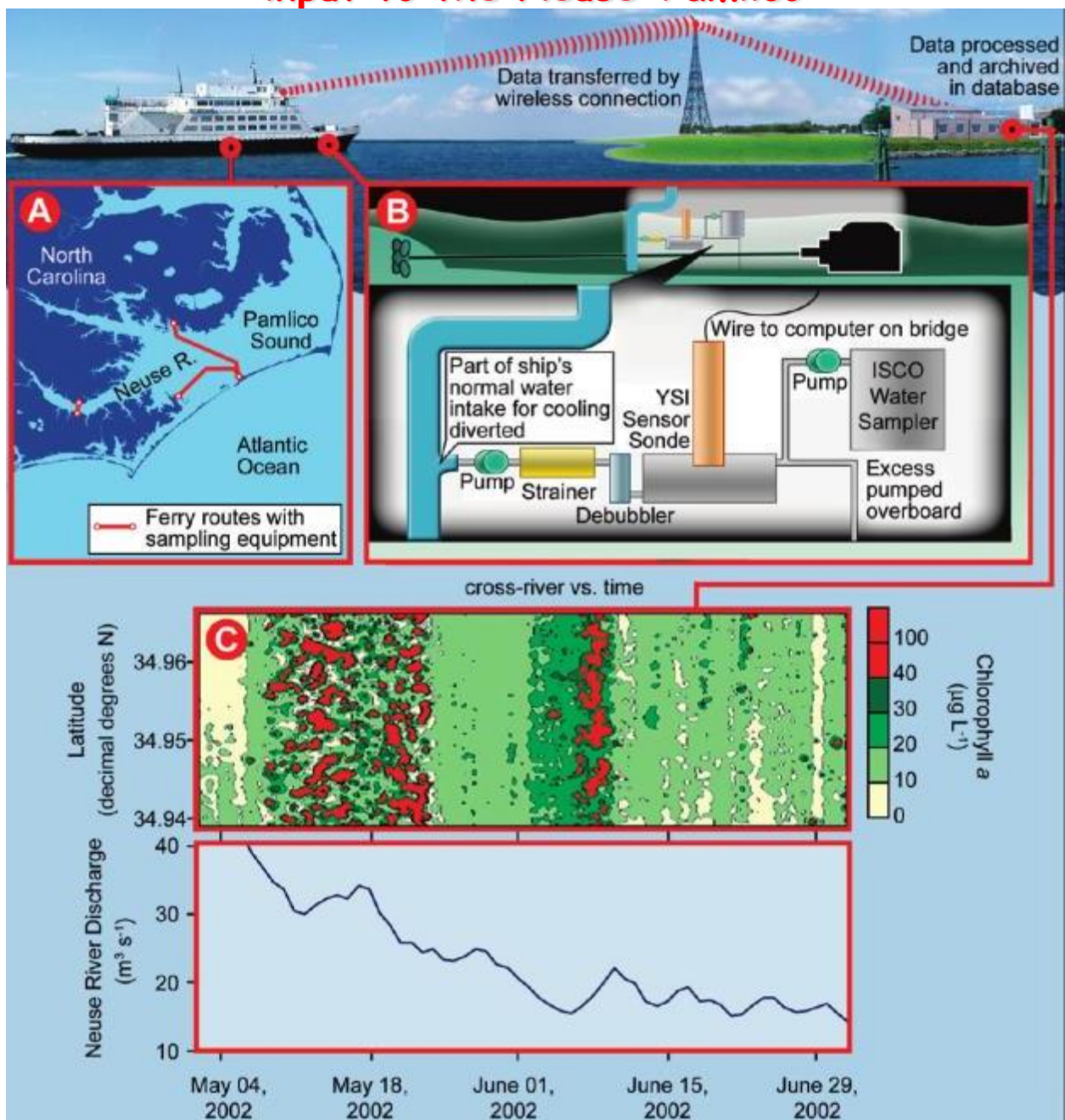
Important for water quality & larval dispersal

Measuring Water Clarity



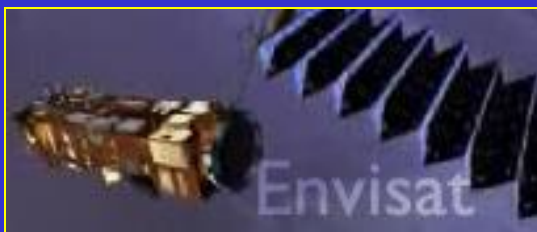
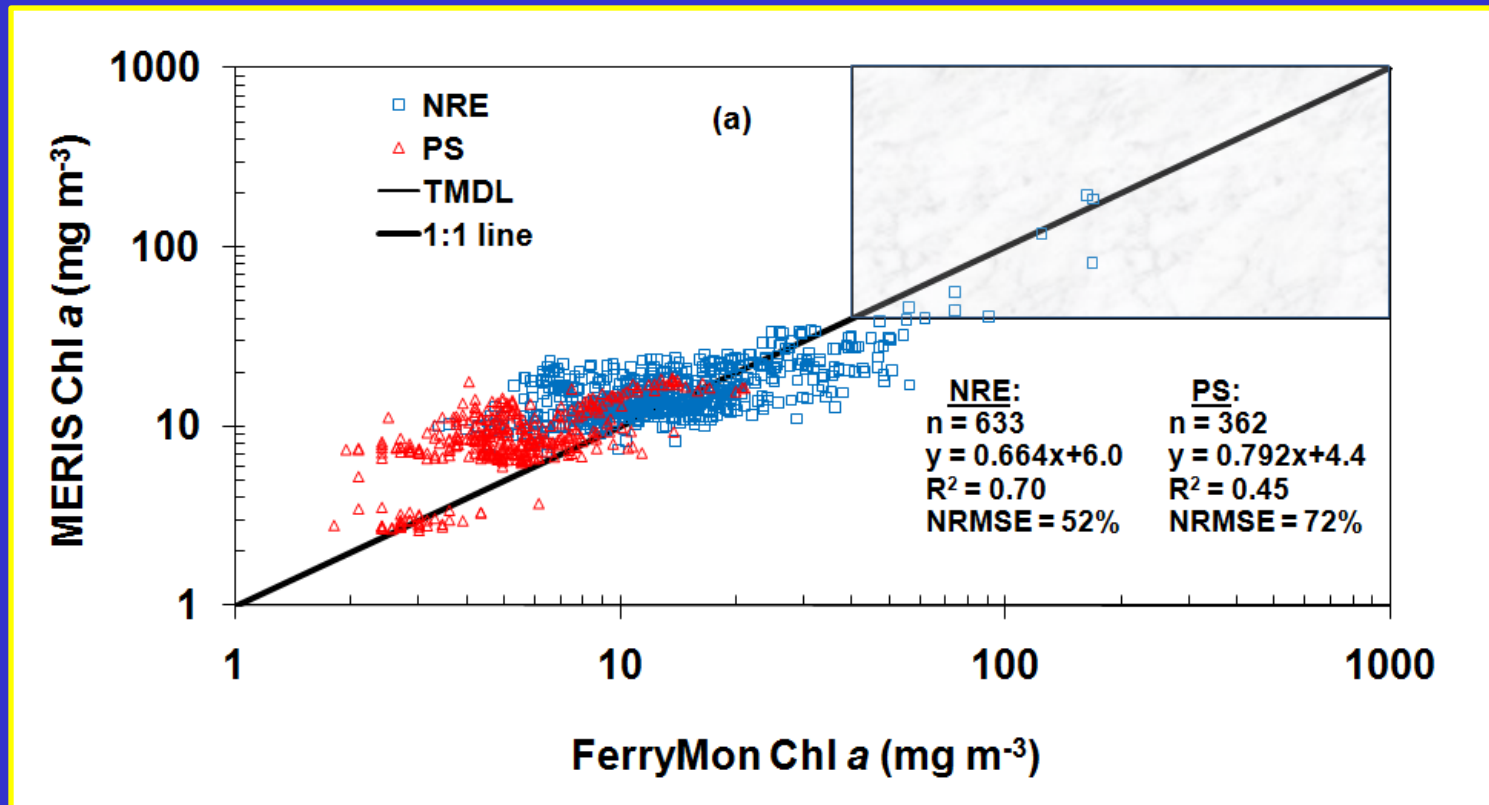
Modeled K_{PAR} Based On Sum

Linking WQ indicators to freshwater discharge and anthropogenic nutrient input to the Neuse-Pamlico



Scaling up: Satellite Based Remote Sensing

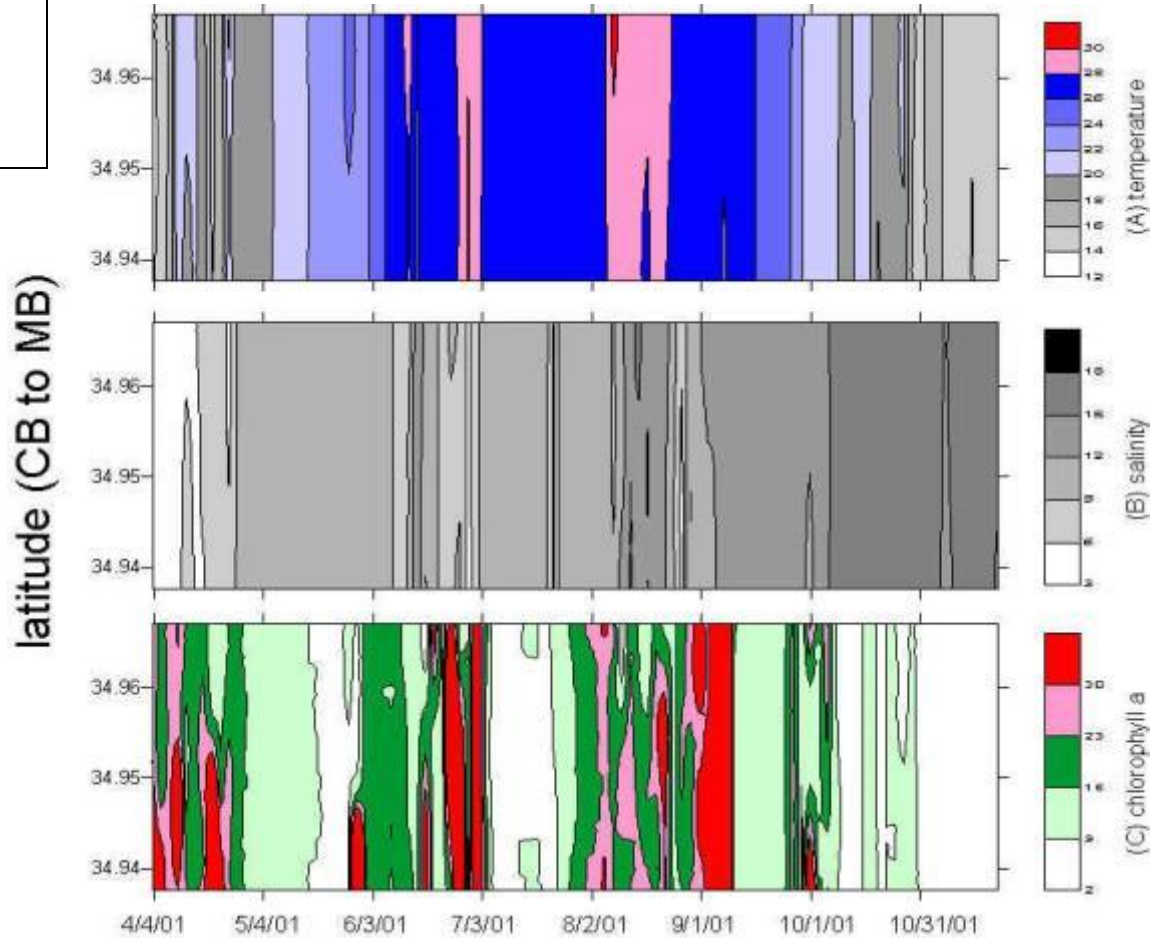
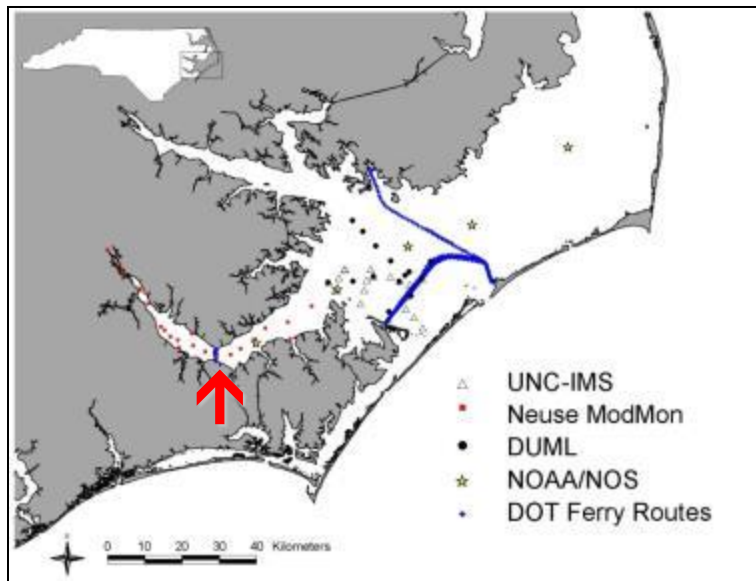
FerryMon Ground Truth Data Used To Calibrate/ Validate Algorithms
(MERIS Imagery, European Space Administration- Envisat Satellite)



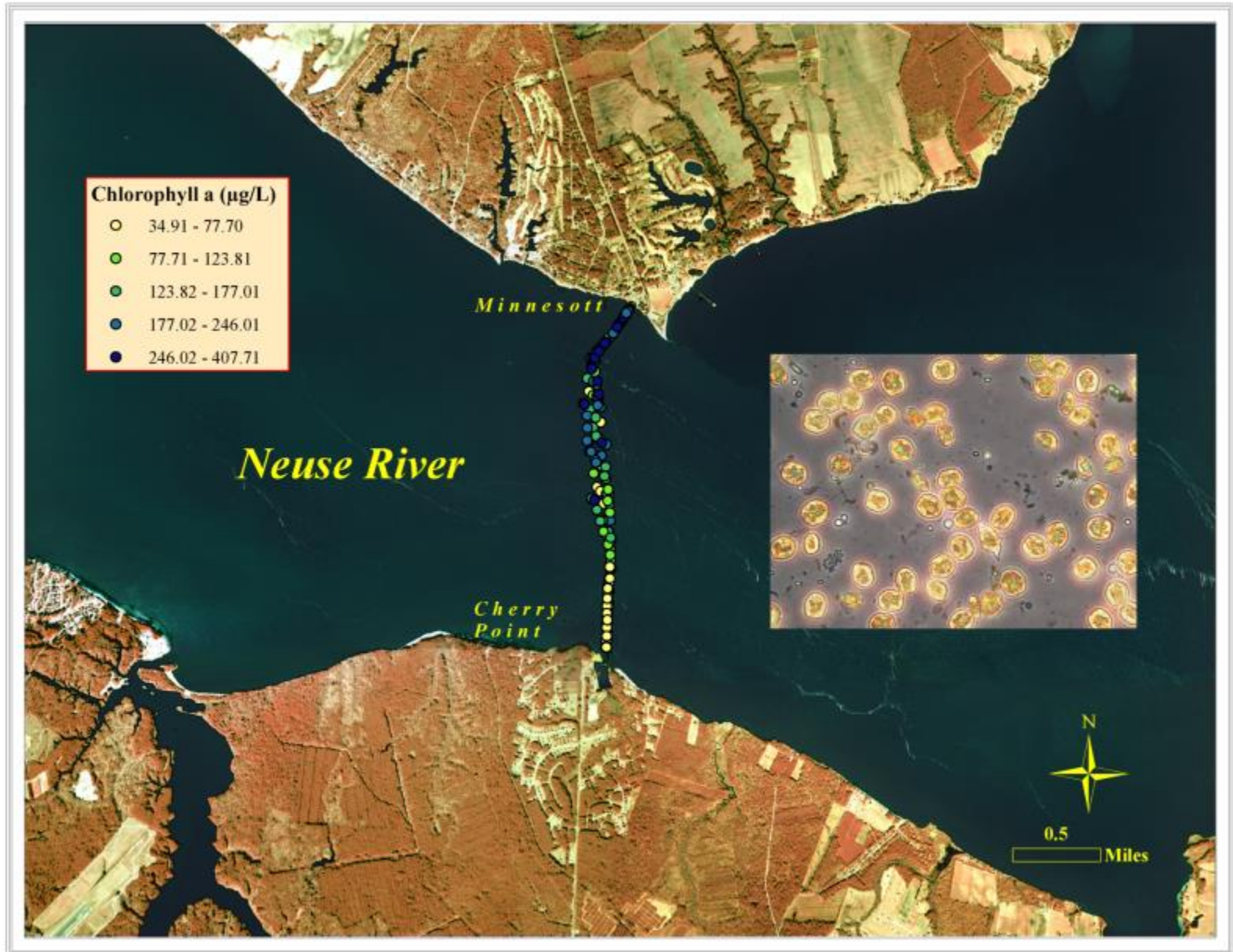
Sokoletsky et al. 2011

Detection and Quantifying Chl *a* & Algal Blooms

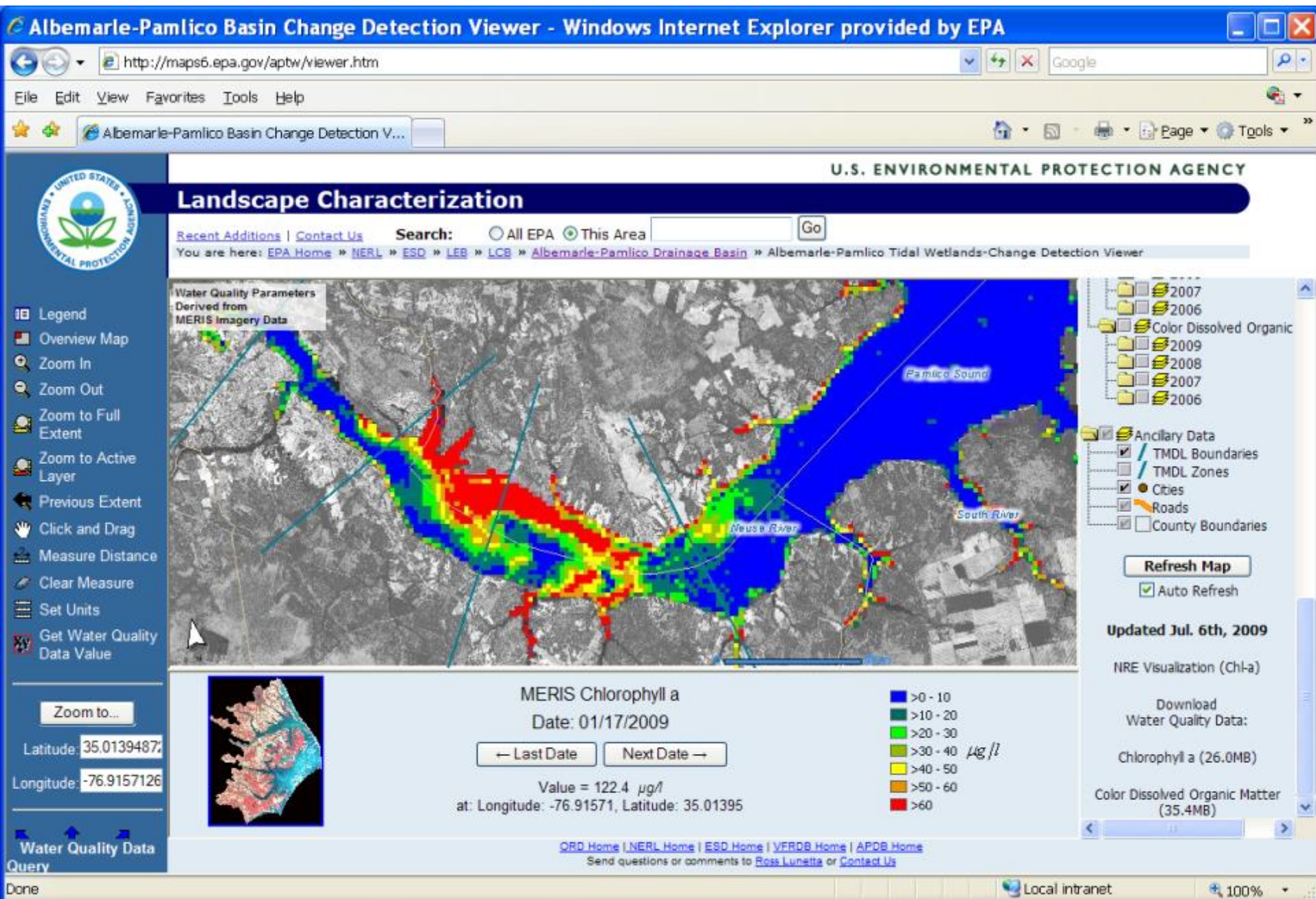
Cherry Branch-Minnesott Ferry



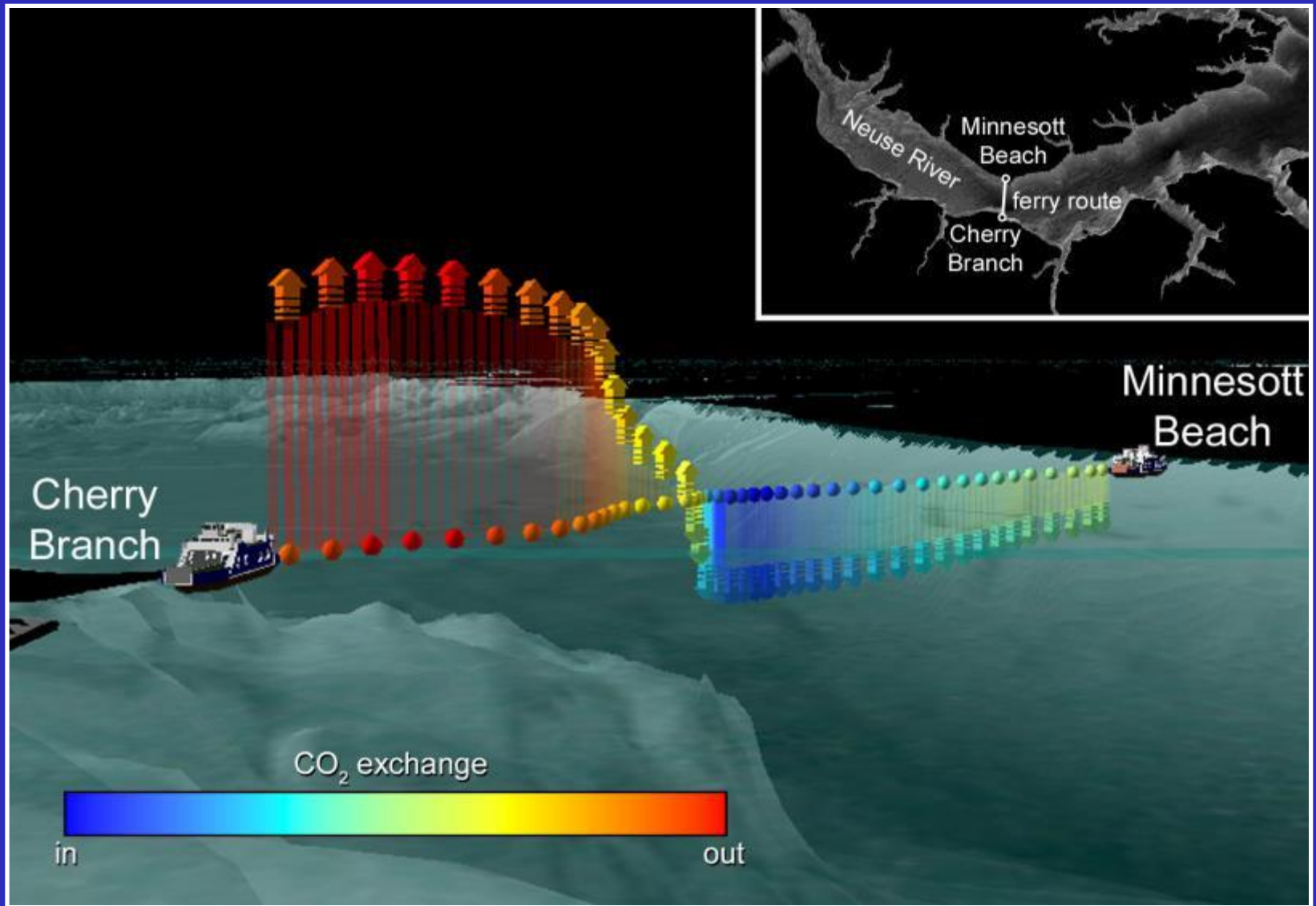
FerryMon: Characterizing a toxic dinoflagellate Bloom March 22-23rd, 2007



Linking to remote sensing (MERIS) to "Scale up" to the entire estuary

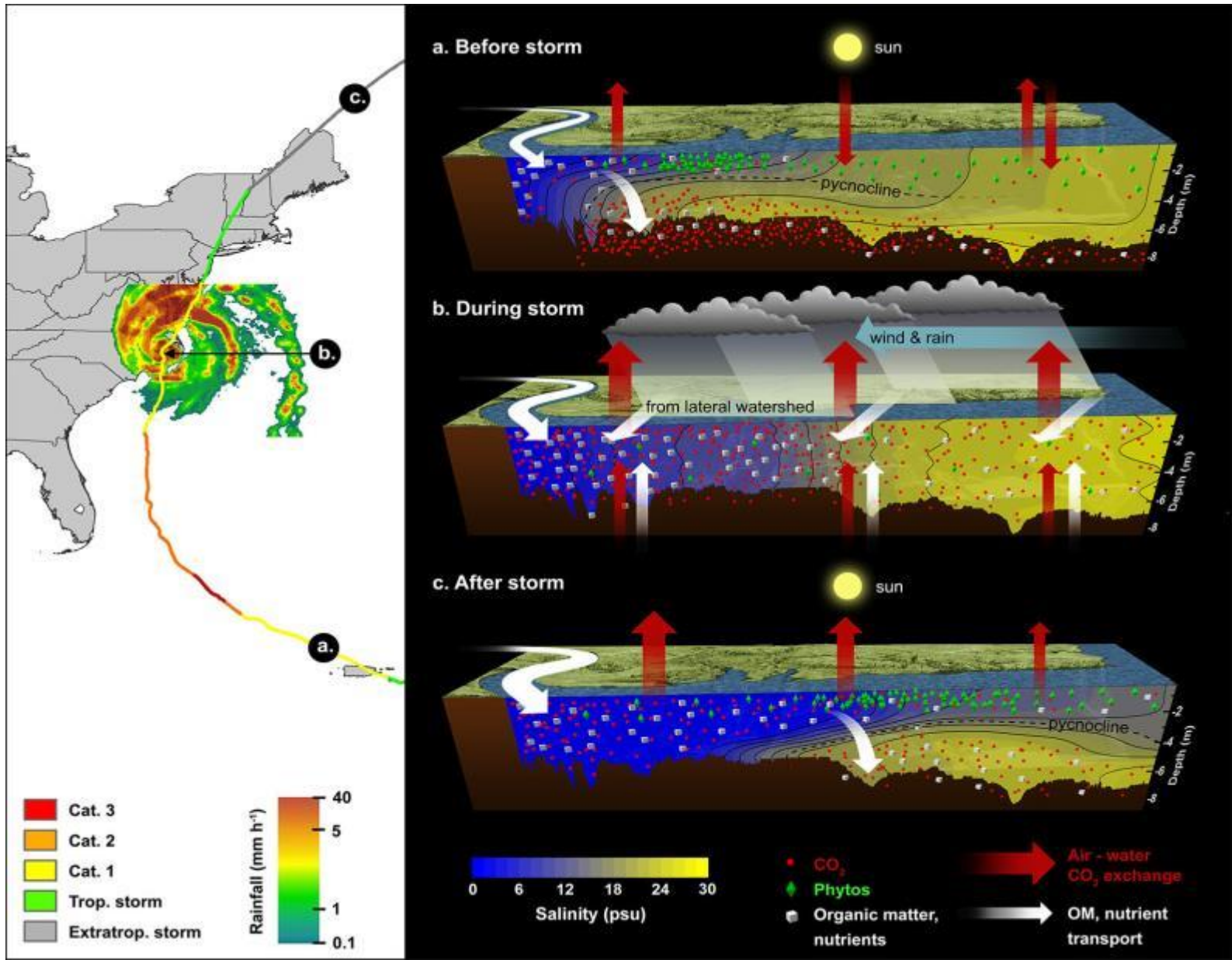


Coupling this to Direct Measurements of Net Ecosystem Metabolism ($p\text{CO}_2$)

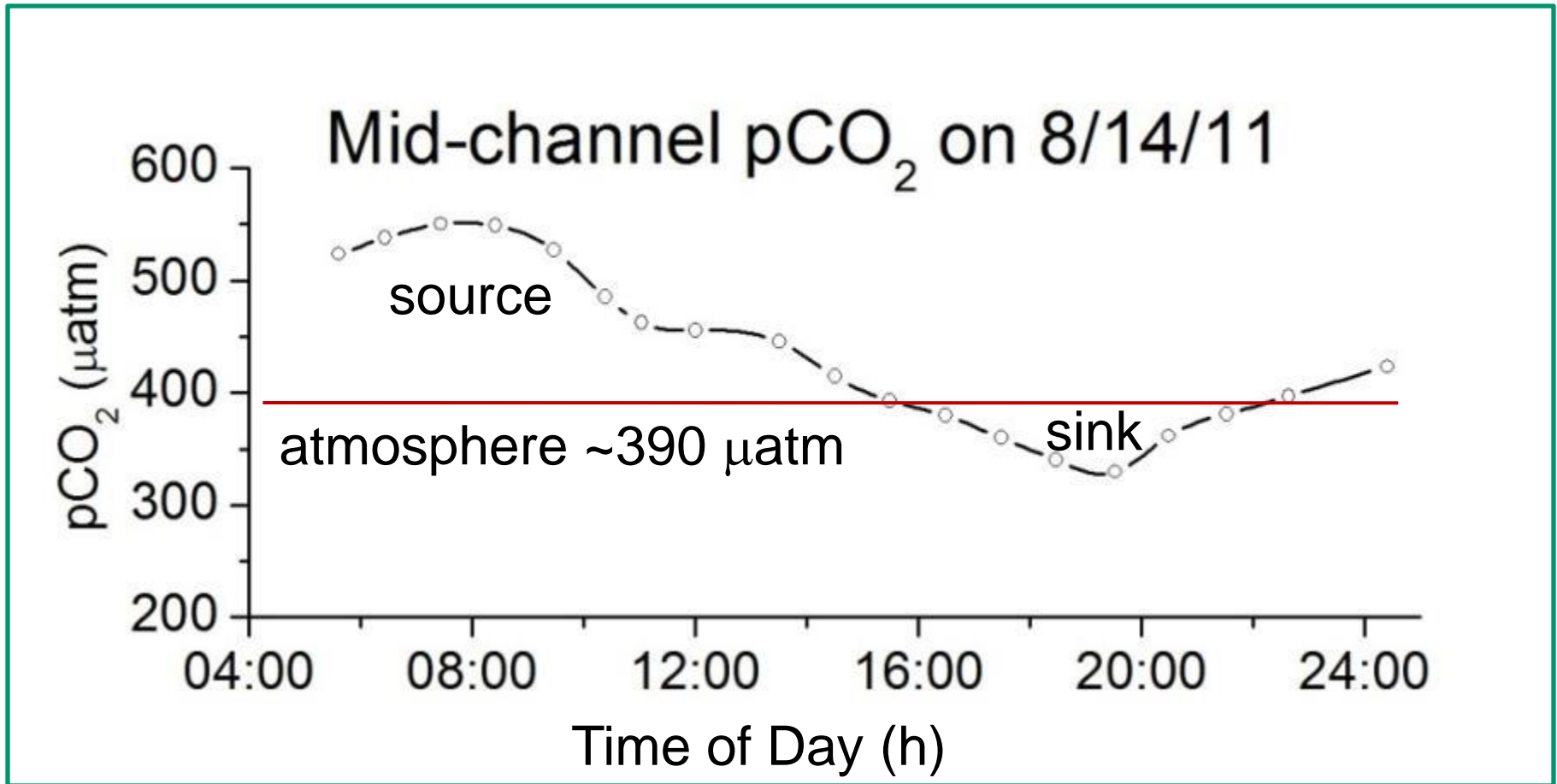


Crosswell et al., 2012

Impacts of a tropical cyclone on pCO₂ in a stratified estuary: Hurricane Irene, Aug 27-28, 2011



Impact of Phytoplankton Production & Respiration on Diel Fluctuations in $p\text{CO}_2$ Revealed by FerryMon in the Neuse River Estuary



Getting organized on the other side of the pond:

Ferries as Part of US Integrated Ocean Observing System (IOOS)

**FERRY-BASED SAMPLING FOR COST-EFFECTIVE, LONG-TERM, REPEAT TRANSECT
MULTIDISCIPLINARY OBSERVATION PRODUCTS IN COASTAL AND ESTUARINE ECOSYSTEMS**
D.L. Codiga¹, W.M. Balch², S.M. Gallagher³, P.M. Holthus⁴, H.W. Paerl⁵, J.H. Sharp⁶, R.E. Wilson⁷

1Graduate School of Oceanography, University of Rhode Island, Narragansett, RI, USA

2Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA

3Biology Department, Woods Hole Oceanographic Institution, Woods Hole, MA, USA,

4World Ocean Council, Honolulu, HI, USA

5Institute of Marine Sciences, The University of North Carolina at Chapel Hill, Morehead City, NC, USA

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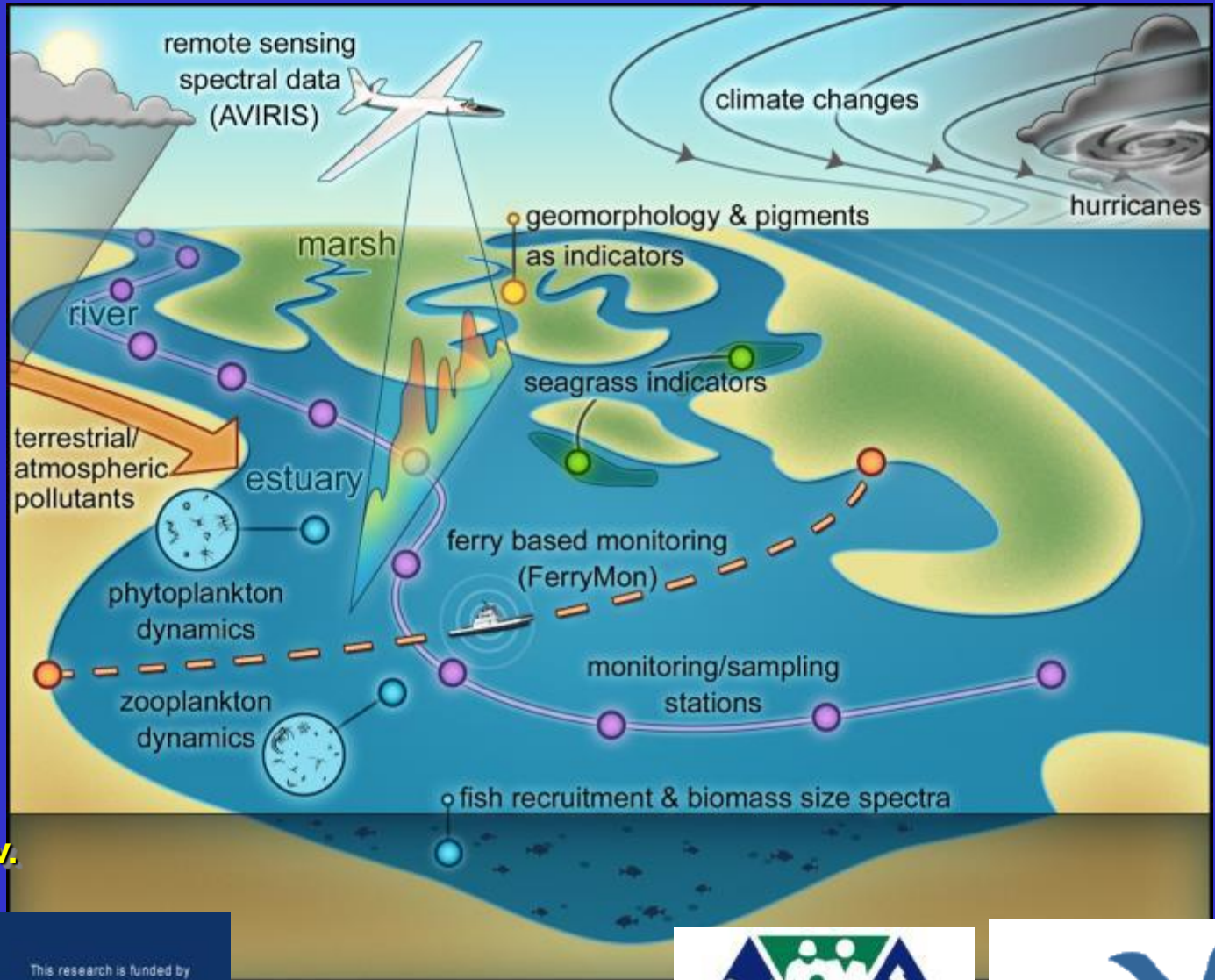
7School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY, USA

Table 1. Established automated-sensor ferry-based sampling programs in the US.

Waterbody	Ves-sels	Sen-sors ^a	Main End Users ^b	Ferry Operator (Public or Private)	Program Coordinators	Funding Agencies
Puget Sound, WA	5-6	MET	P, FO, B	WA State Ferries (Public)	UW Atmospheric Sciences; WA DOT	US DOT / WA State
Pamlico Sound, NC	3	WQ ^c	WM, FM, UR, AR, NGO, K12, MA, F, P	NC DOT Ferry Division (Public)	UNC Chapel Hill ; Duke U.; NC Dept Env. Nat. Res.	NC Dept. Env. Nat. Res. / NSF: Engin.; Chem. Oce.; Ecosyst. Stud. / NC Sea Grant
Delaware Bay, DE	1	WQ ^d MET	UR, AR, WM, FM, FO, P	Delaware River and Bay Authority (Public)	University of Delaware	DE Sea Grant
Central Long Island Sound, NY & CT	1	VEL WQ ^e MET ^f	UR, FO, B, P	Bridgeport Port Jefferson Ferry Co. (Private)	Stony Brook University	National Weather Service / NY Sea Grant / EPA Long Island Sound Office
Eastern Long Island Sound, NY & CT	1	VEL WQ	UR, P	Cross Sound Ferry Services, Inc (Private)	University of Rhode Island	CT Sea Grant / EPA Long Island Sound Office / NSF Phys. Oce.
Vineyard/ Nantucket Sounds, MA	2	WQ ^g	UR,P	Woods Hole, Martha's Vineyard and Nantucket Steamship Authority (Public)	Woods Hole Oceanographic Institution	Woods Hole Sea Grant
Gulf of Maine, ME	1	WQ ^h	UR, AR	Bay Ferries Ltd. ¹ (Private)	Bigelow Laboratory for Ocean Sciences	NASA



Thank You!!



Special Thanks to:

**Betsy Abare
Tim Boynton
Jeremy Braddy
Larry Harding
Ross Lunetta
Joseph Ramus
Randy Sloup
Pam Wyrick**

& NC DOT Ferry Div.



www.ferrymon.org

