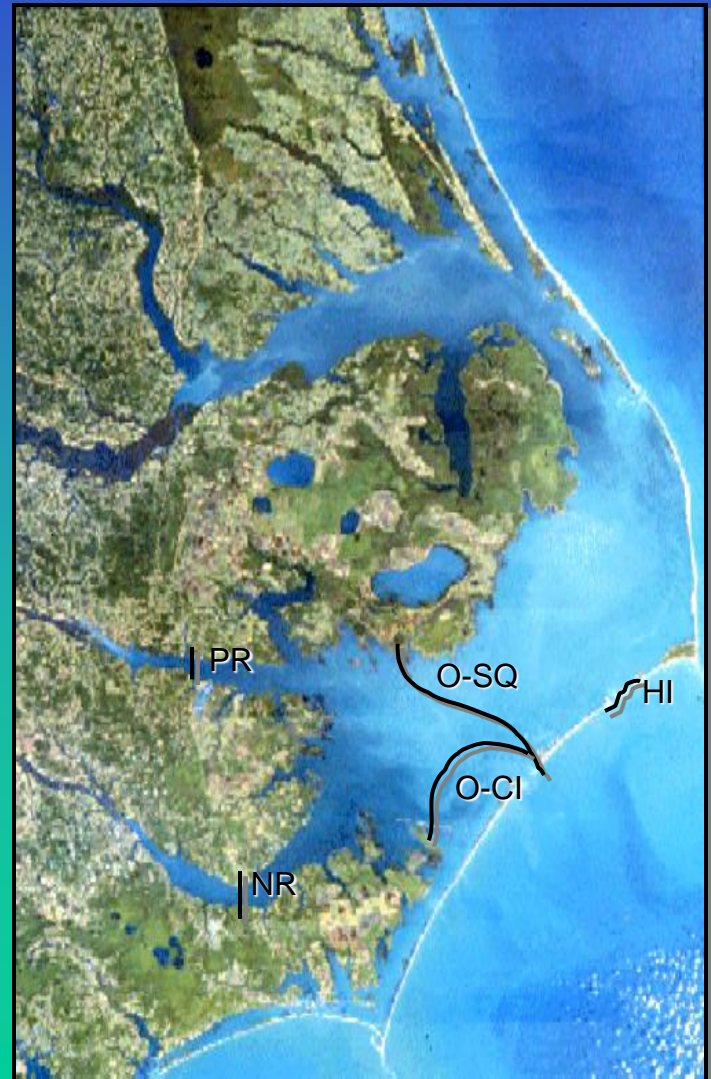


FerryMon: Unattended ferry-based water quality monitoring to evaluate human and climatically-driven ecological change in the Pamlico Sound Estuarine system, North Carolina, USA

Hans Paerl, Benjamin Peierls, Karen Rossignol, Joseph Crosswell and Jeremy Braddy, UNC-CH Institute of Marine Sciences, Morehead City, NC



www.ferrymon.org



Pamlico Sound System: The Problems, Research/Monitoring Challenges

Excessive nutrient loading → eutrophication → hypoxia → WQ/habitat decline

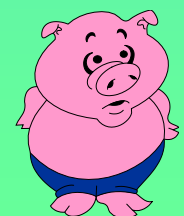
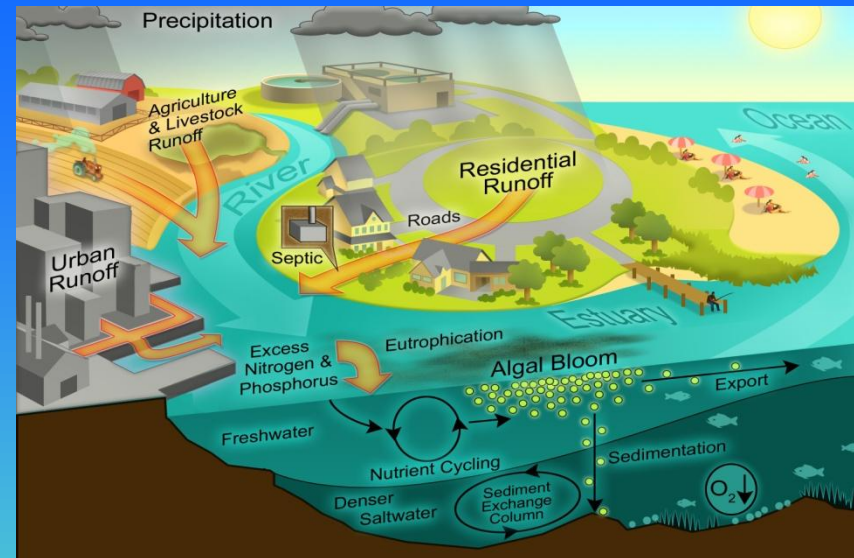
- 2nd largest Estuary in US

- Drains NC/VA coastal plain

- >40 years of agricultural, urban & industrial expansion

- Increased N and P loading, eutrophication, harmful algal blooms, hypoxia, fish kills

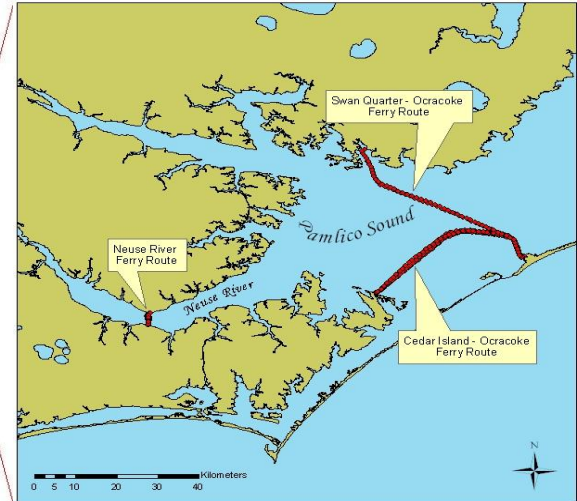
- Site of increased tropical cyclone activity (11/last 10 years, including Irene, 27-Aug.)



FerryMon Applications

- Develop WQ data baseline against which to gauge ecological change in Pamlico Sound
(Users: North Carolina DENR, EPA)
- Utilize multiple indicators to evaluate WQ criteria
(Users: North Carolina DENR, EPA, NOAA, NASA)
- CO₂ Flux measurements & relate to biological activity
 - Data for WQ & Observational Data Models
(Users: N.C.-DENR, EPA, public, educational institutions, ~ 100k "hits" on website/yr)
 - Calibrate Remote Sensing for "scaling up" to System/Regional Level
(Users: EPA, NASA, USDA)
- Assess Human vs. Climatic Influences on WQ

Using FerryMon to assess ecological conditions in the Pamlico Sound

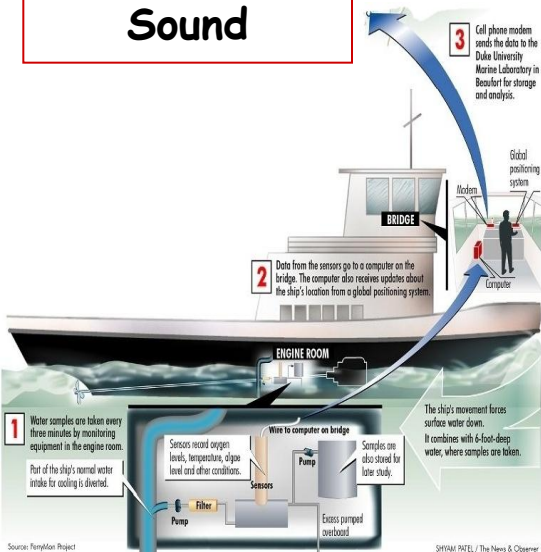


Raw Data Sent via Modem to UNC-IMS

Raw Data Stored at IMS

Raw Data Text Files QA/QC'ed

QA/QC'ed Data added to Microsoft Access Database



Ferry Bridge Equipt

Date/Time

DGPS Latitude / Longitude

Data Modem / Data Logger



ISCO discrete sampler

in-situ Chla

in-vivo Chla

Diagnostic Pigments

Nutrients

E. Coli / viruses

Date/Time

YSI sonde

in-situ Chla

Salinity/Temp

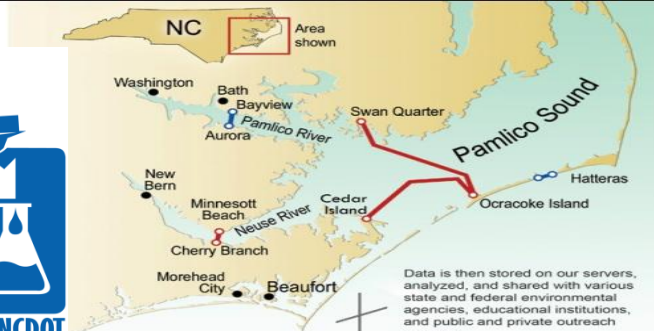
Turbidity

pH/DO

PCO₂

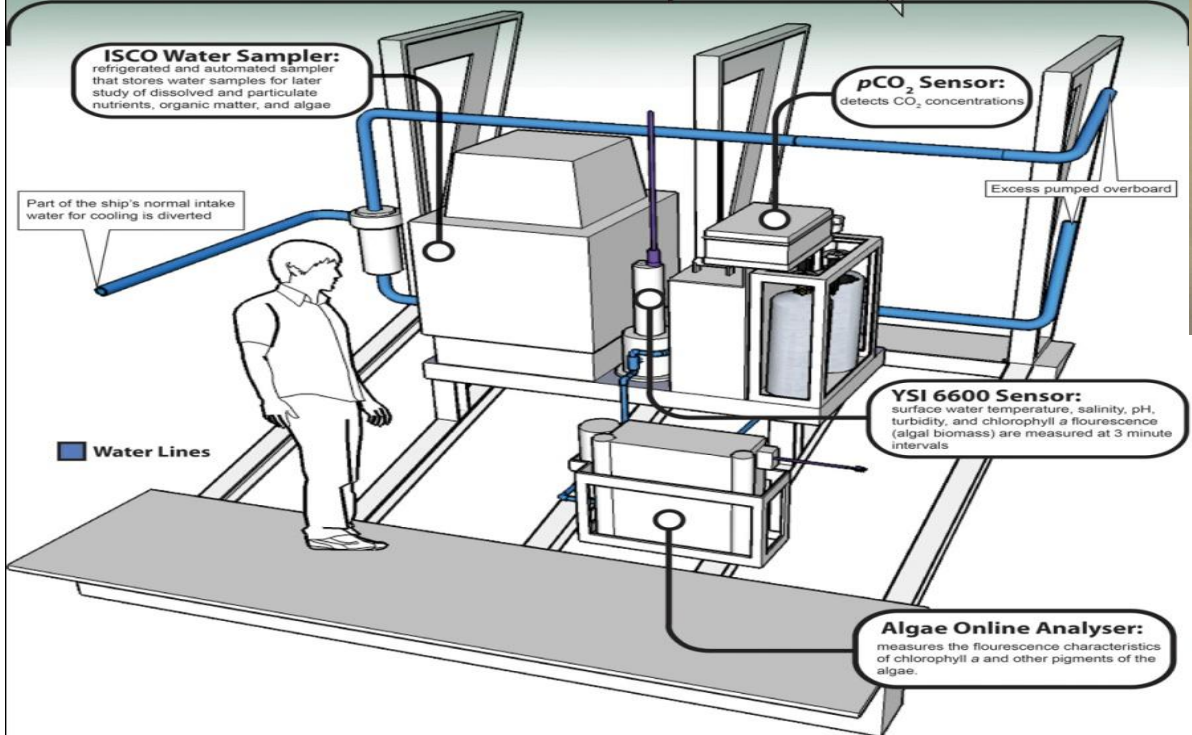
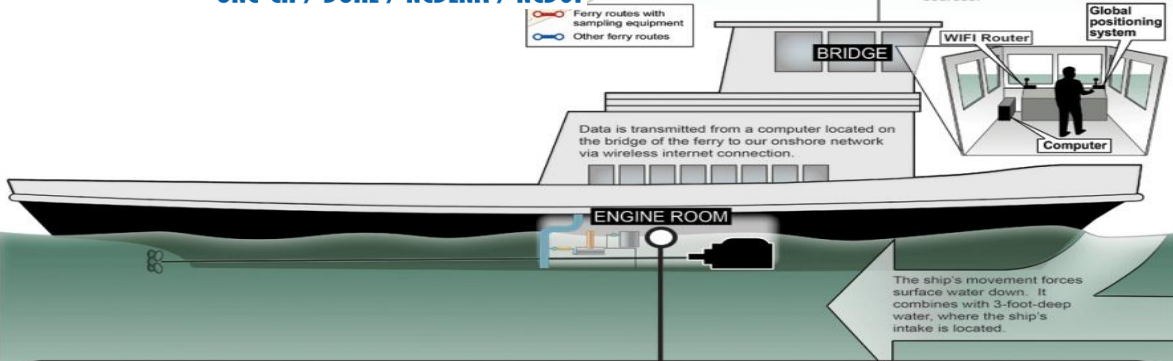
Date/Time





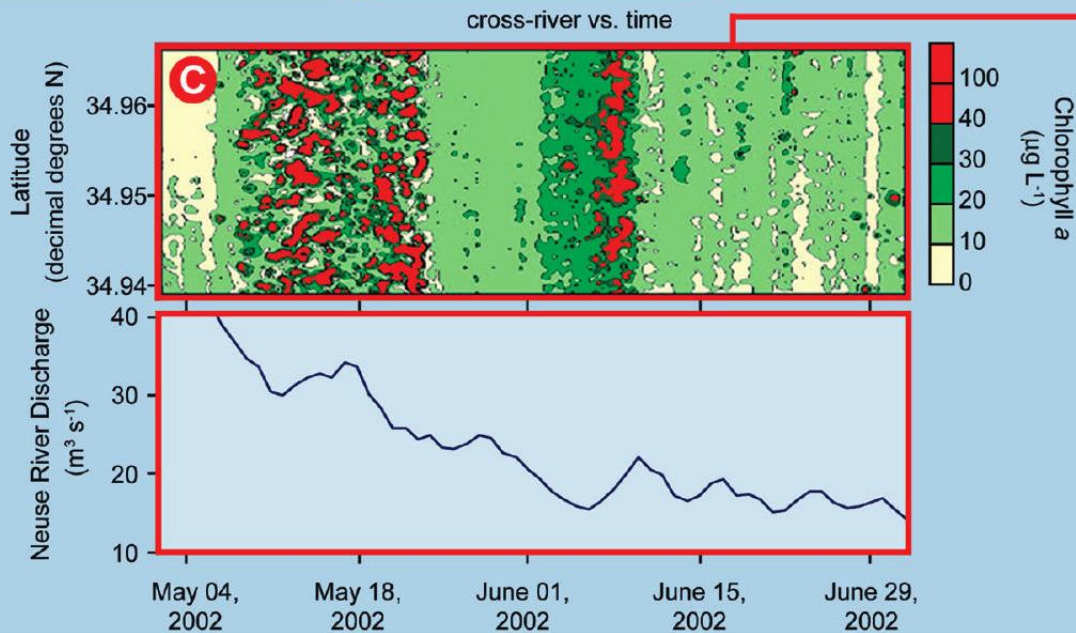
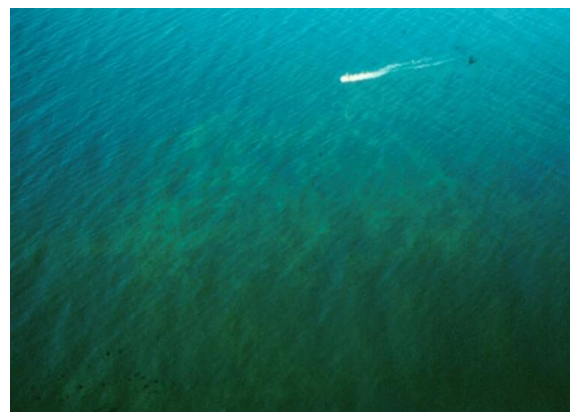
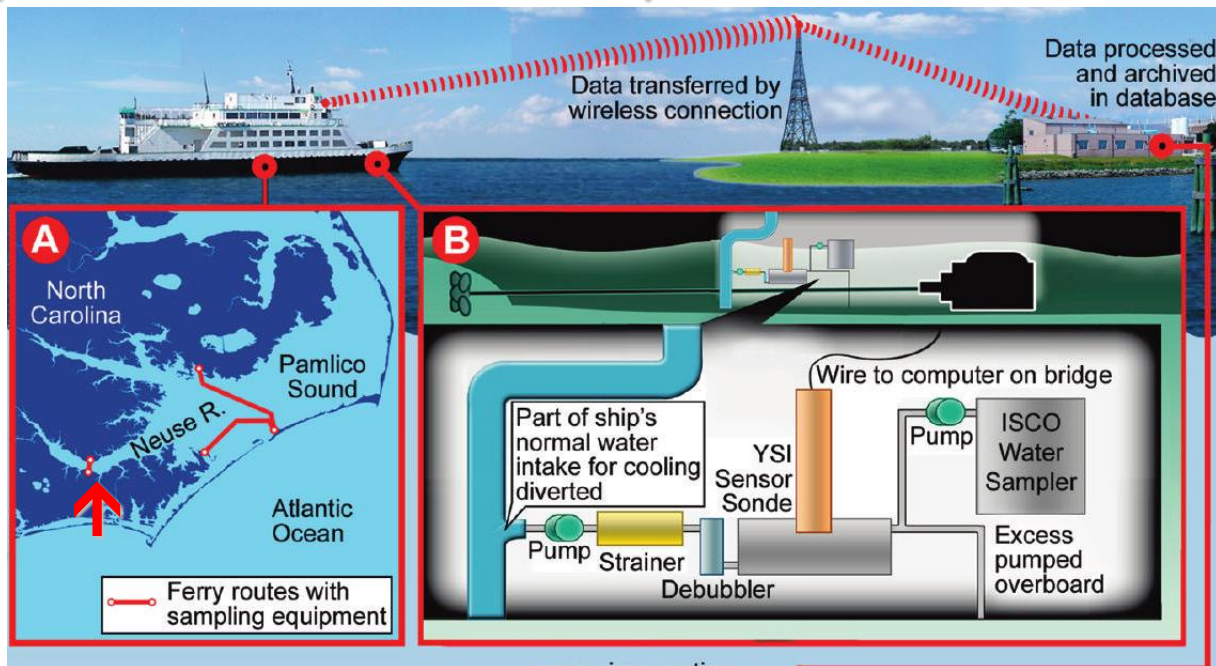
Data is then stored on our servers, analyzed, and shared with various state and federal environmental agencies, educational institutions, and public and private outreach sources.

The "heart" of FerryMon

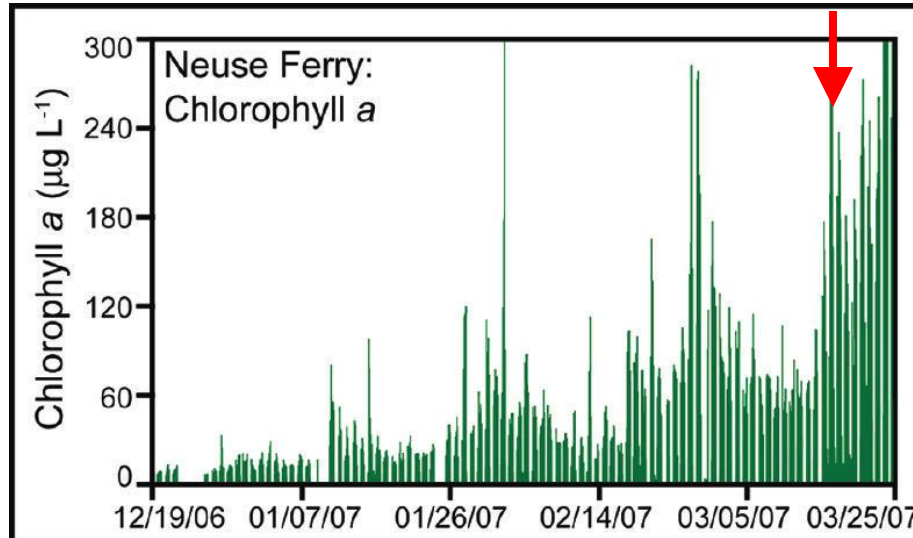


Quantifying Chlorophyll *a* & Detecting Algal Blooms

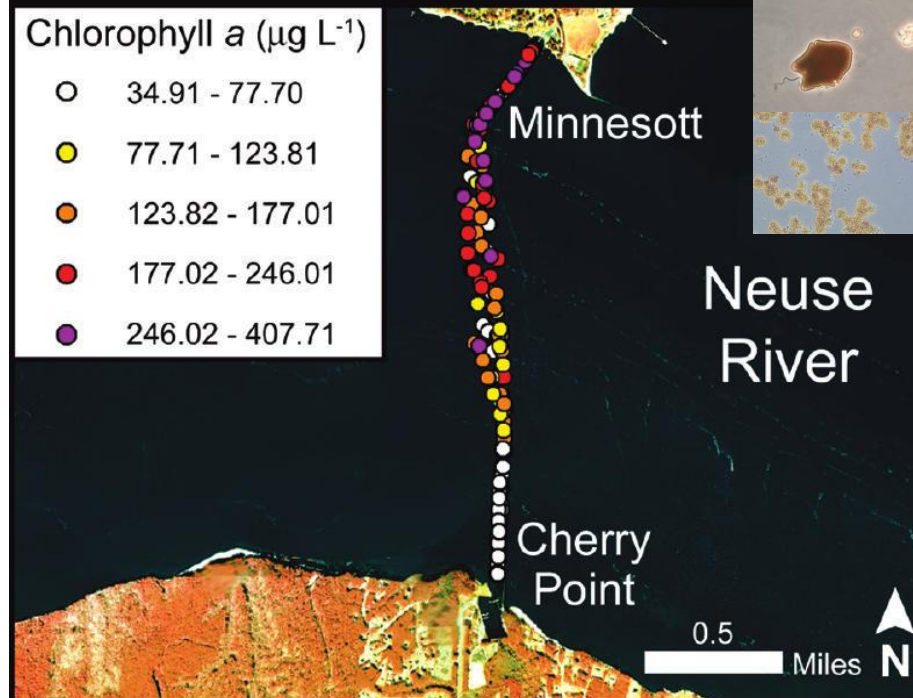
Cherry Branch-Minnesott Ferry



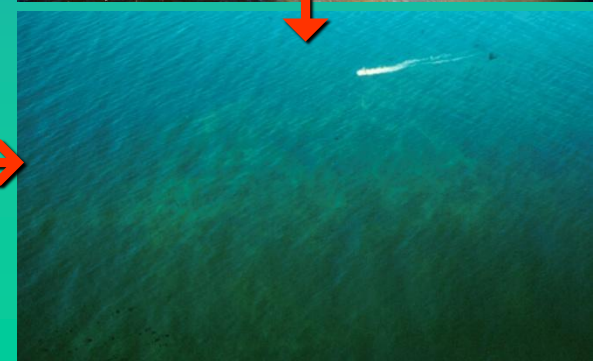
Spatial analysis of blooms: Dinoflagellate Bloom March 22-23rd, 2007



Neuse River: March 22-23, 2007



Assessing WQ responses to extreme climatic events: TS/Hurricanes of '96, '99, '03, '05, '06, '10, '11 & ????



From an estuarine/coastal perspective, why the fuss about hurricanes and tropical storms?

Large Hydrologic perturbations

(lots of water, quickly, and persistent flooding in low-lying areas)

Increased Nutrient and other contaminant inputs

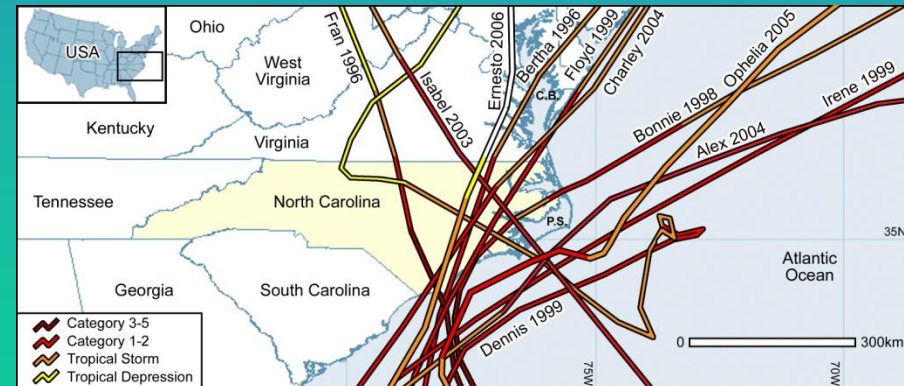
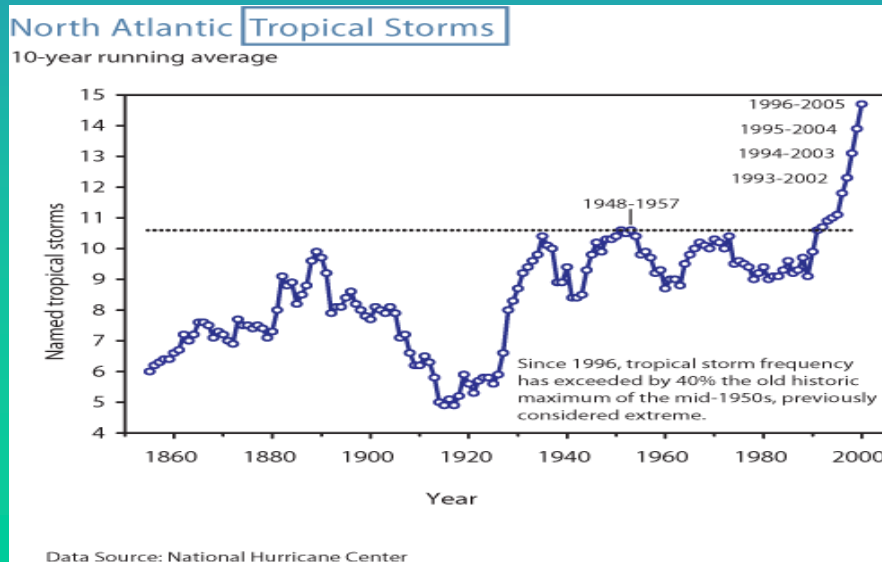
Changes in sediment dynamics (transport, deposition, resuspension)

Biotic alterations (water quality, habitat, food webs)

Reason for concern.....

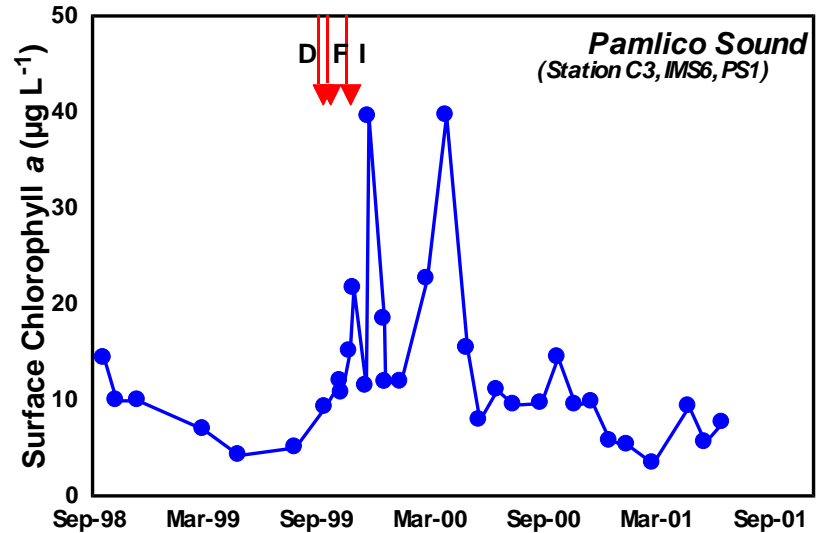
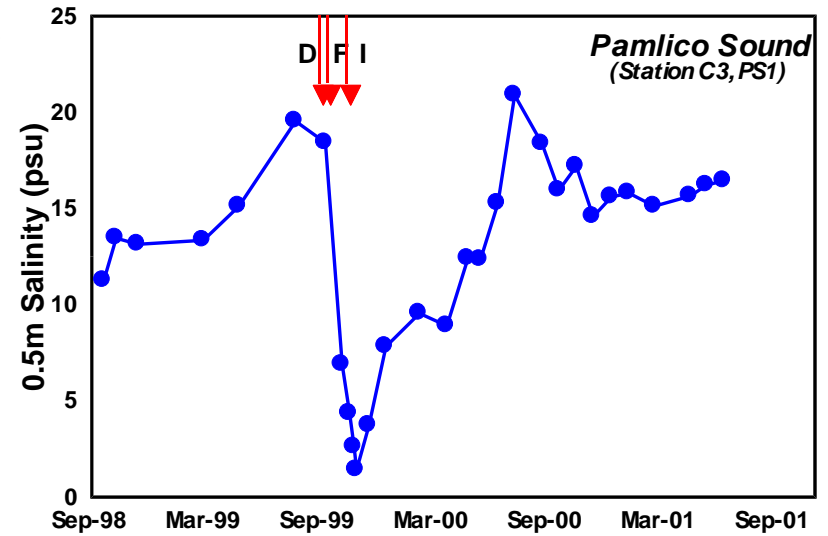
"We appear to be in a period of elevated tropical cyclone activity"

Goldenberg et al. 2001, Webster et al. 2005, Emanuel 2005

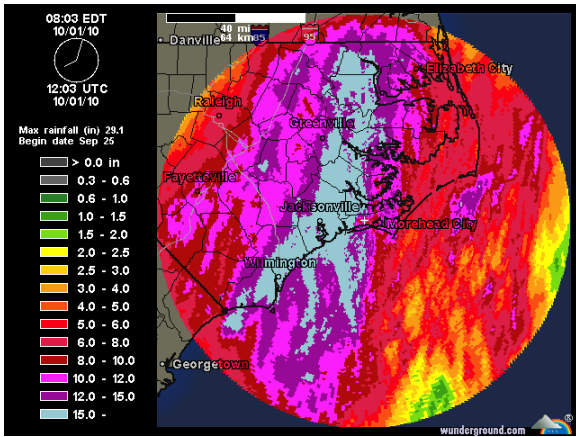


Source:
NOAA, Natl. Hurricane Center

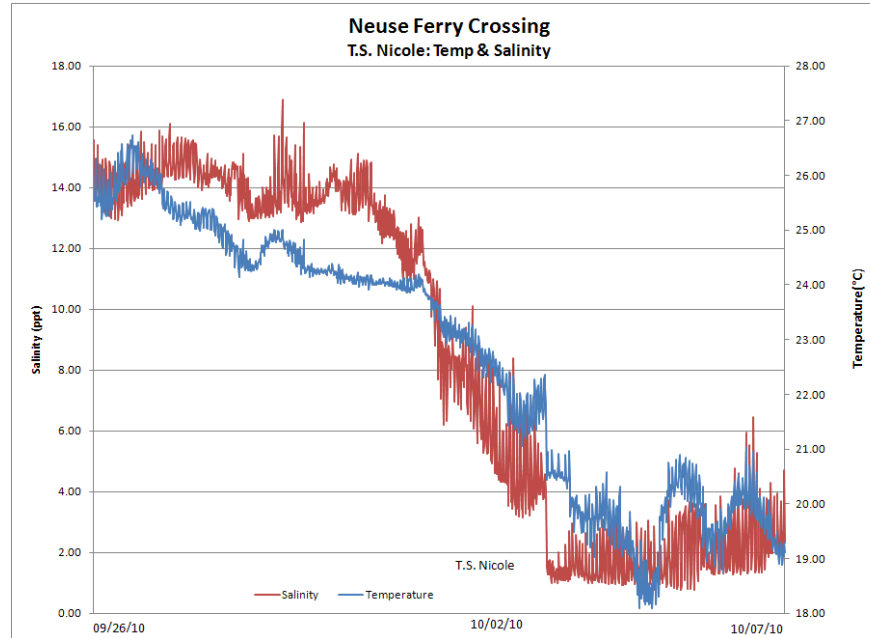
Hurricanes Dennis, Floyd & Irene ('99) Salinity and Chlorophyll *a* responses in the Pamlico Sound



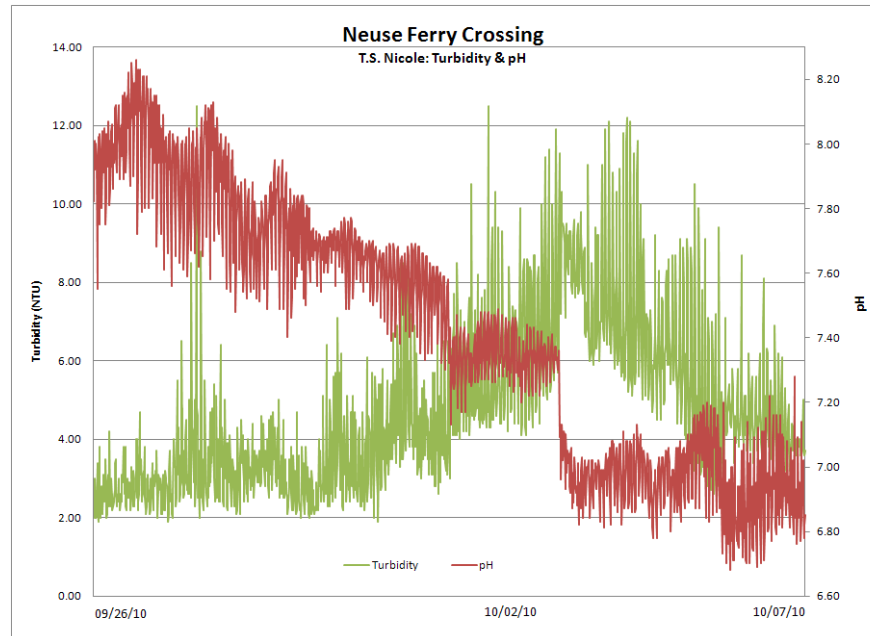
Tropical Storm Nicole, 25 Sept., 2010



Radar-estimated precipitation for North Carolina from Sept. 25-October 1, attributed to Tropical Storm Nicole.



Neuse Ferry Crossing Temperature and Salinity graph during Tropical Storm Nicole, October, 2010.



Turbidity and pH of Neuse River during Tropical Storm Nicole. Turbidity increased with increased wind and runoff, while pH dropped due to high volume of lower pH precipitation

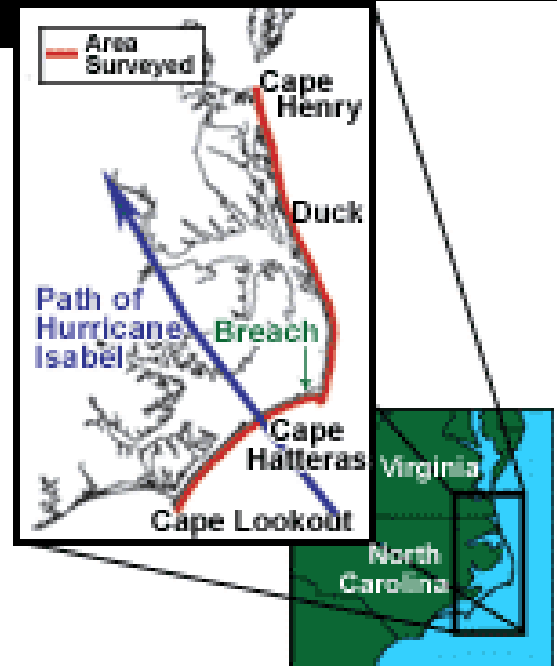
09/08/1999, Before



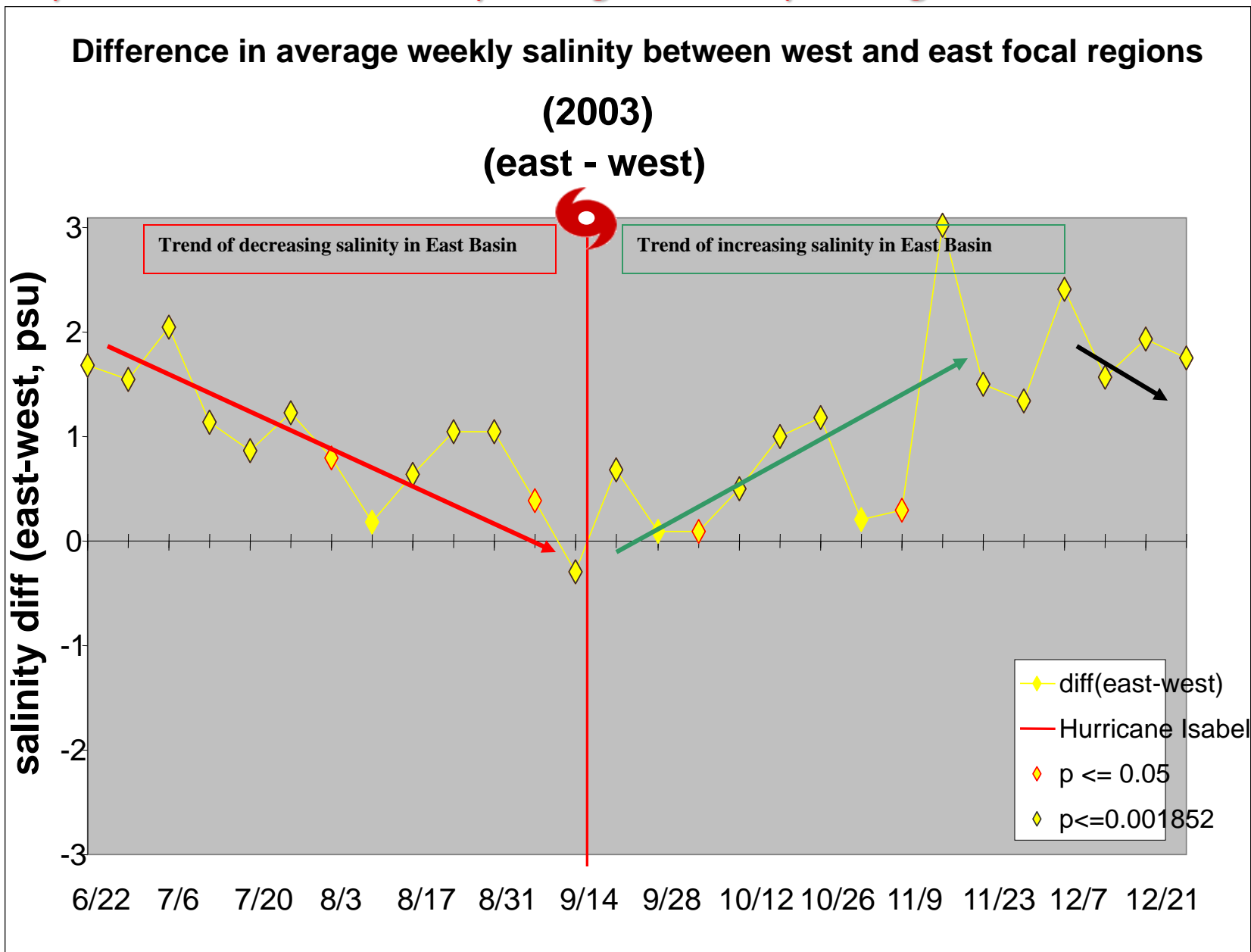
09/21/2003, After



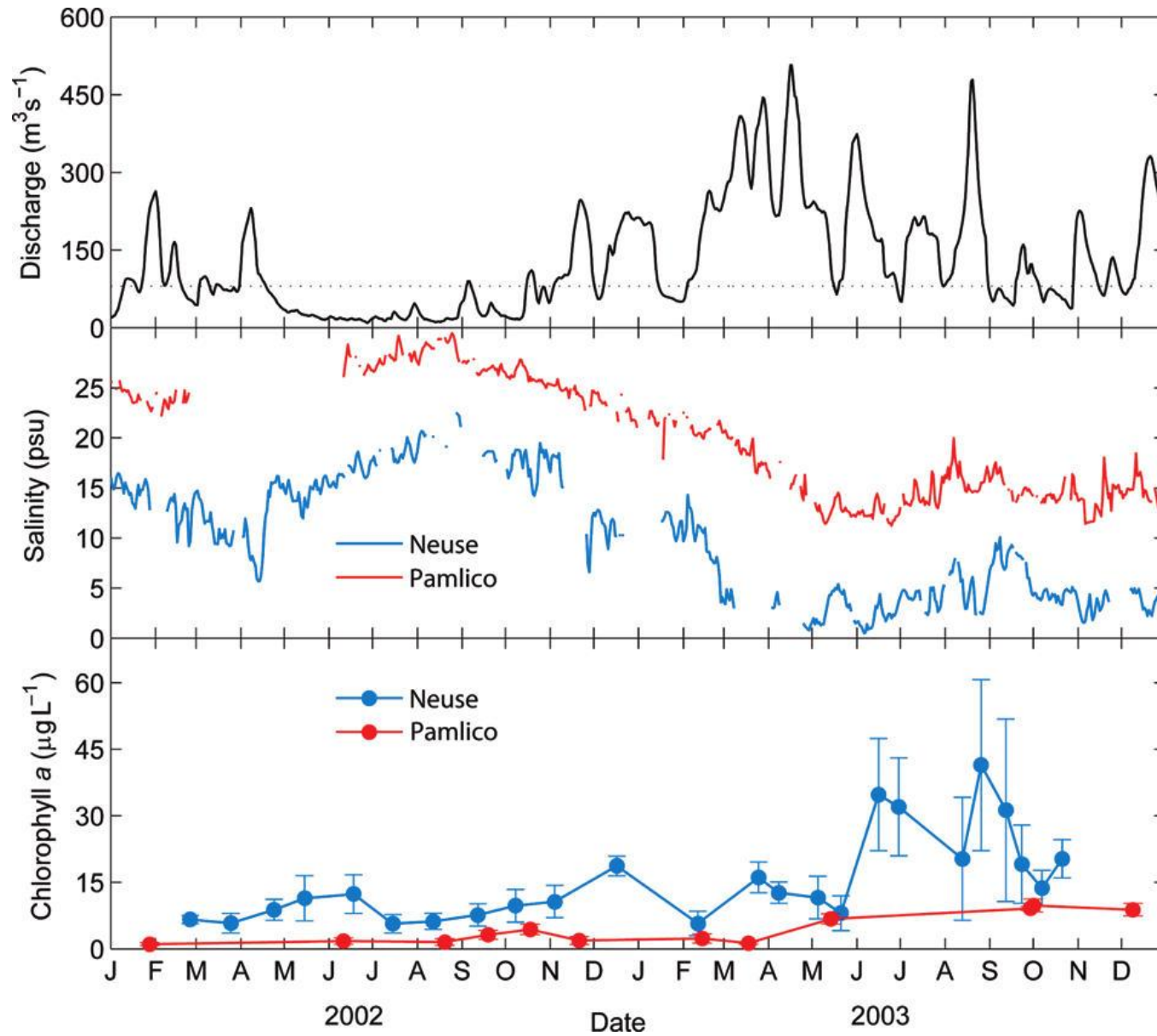
Sept. 2003: Isabel "creates" a new inlet in the Outer Banks



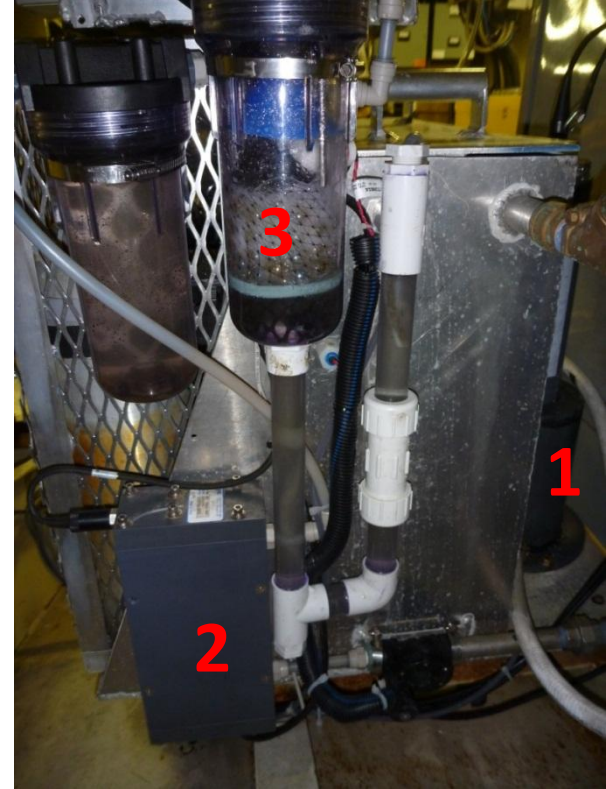
FerryMon characterizes hydrologic/salinity changes in Pamlico Sound



Linking patterns of freshwater discharge, salinity and phytoplankton production



Drivers of CO₂ Flux



1. Sonde (YSI)

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

2. TSG (Seabird)

- Salinity (SSS)
- Temp (SST)



Air-water CO₂ flux



pCO₂

3. Equilibrator

- Temp
- Pressure

4. NDIR CO₂ Analyzer (Licor)

- xCO₂

5. Calibration gas standards



Seasonal Variability: river vs. wind dominated

River Flow Wind

High

5.7

20 Nov 09

Low

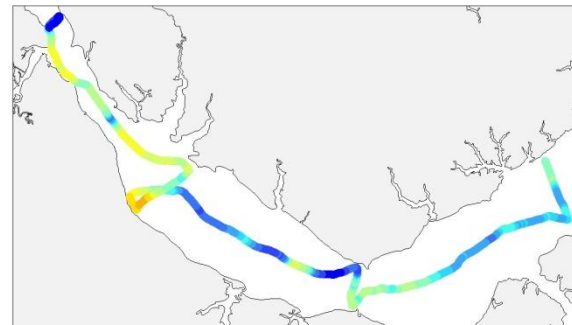
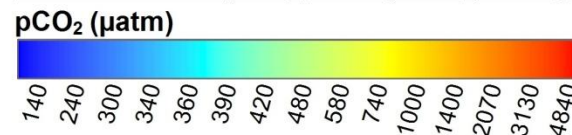
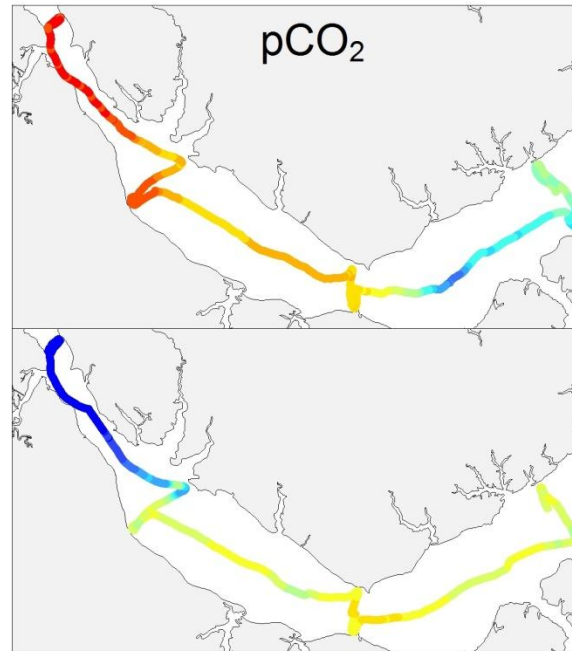
6.9

11 May 10

varied

4.8

21 Jun 10

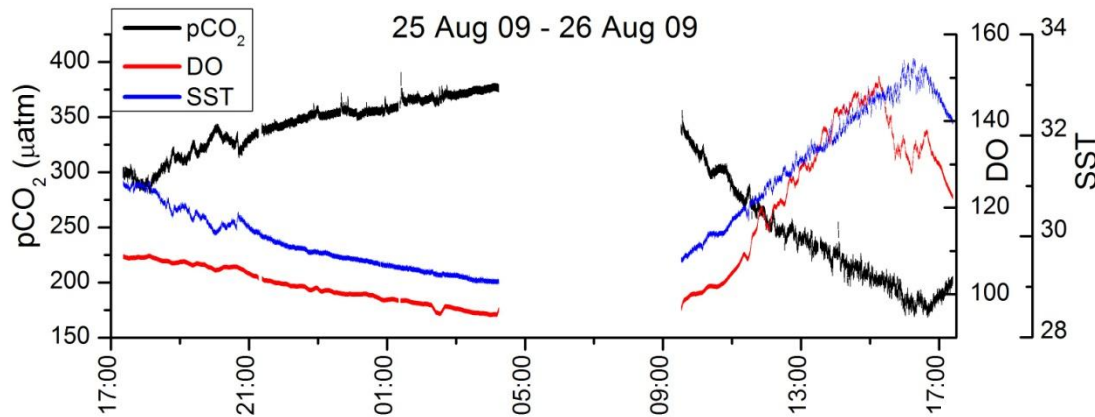
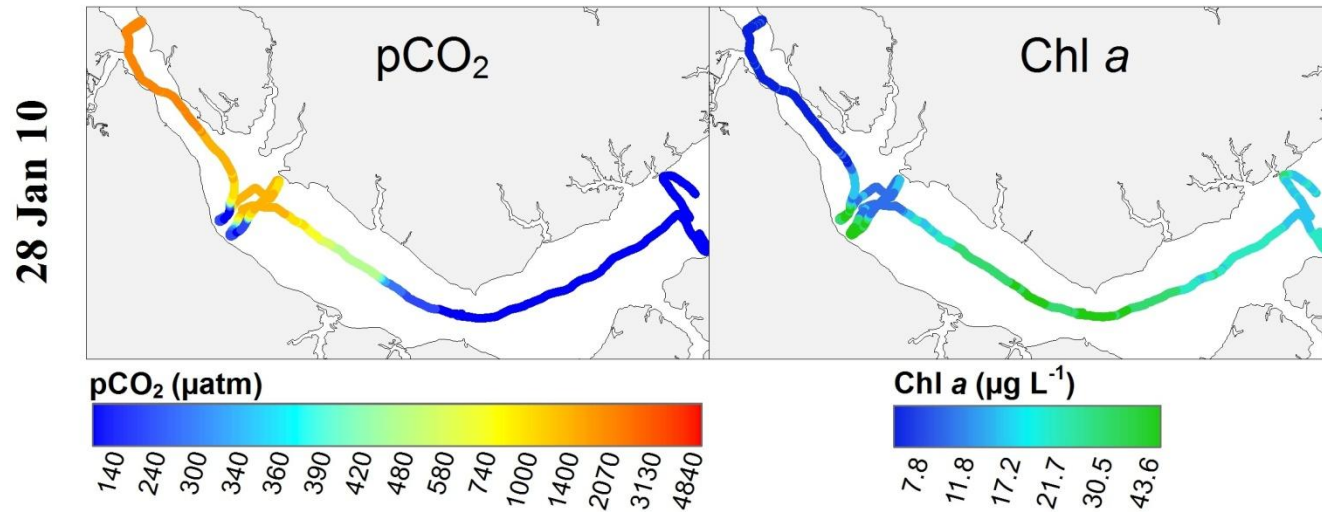


- Decreasing pCO₂
- Increasing pH

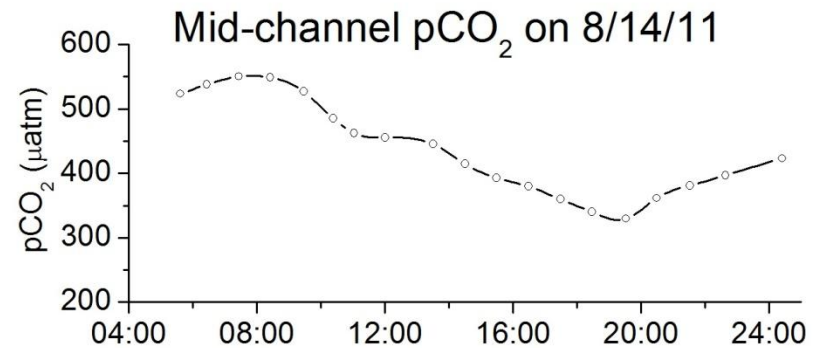
- Along-axis winds
- destratification

- Cross-axis winds
- Up/downwelling

Biological (photosynthesis/respiration) influence



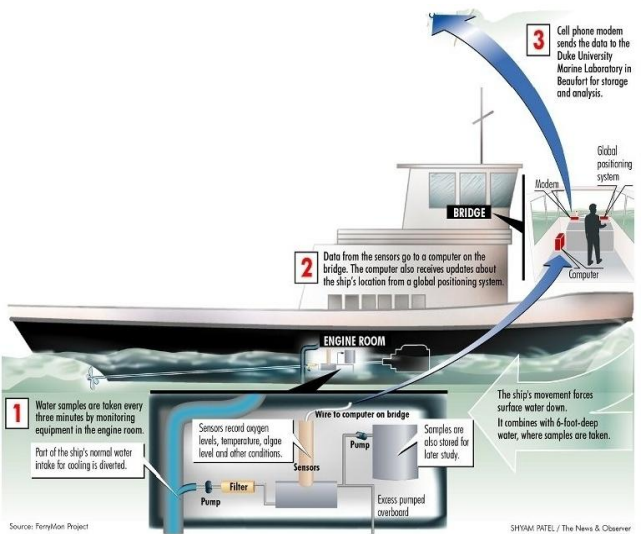
Scales of significant variability:
Spatial: ~100 m
Temporal: hours





UNC-CH / DUKE / NC-DENR / NC-DOT

Neuse-Pamlico Estuarine Routes: www.ferrymon.org



Coupling FerryMon to remote sensing of Pamlico Sound

Swan Quarter - Ocracoke Ferry Route

Neuse River Ferry Route

Pamlico Sound

Cedar Island - Ocracoke Ferry Route

0 5 10 20 30 40 Kilometers

N

- ## Parameters
- Temp.
 - Salinity
 - D.O.
 - pH
 - Turbidity
 - Chl a
 - Diagnostic pigments
 - CO₂
 - Nutrients

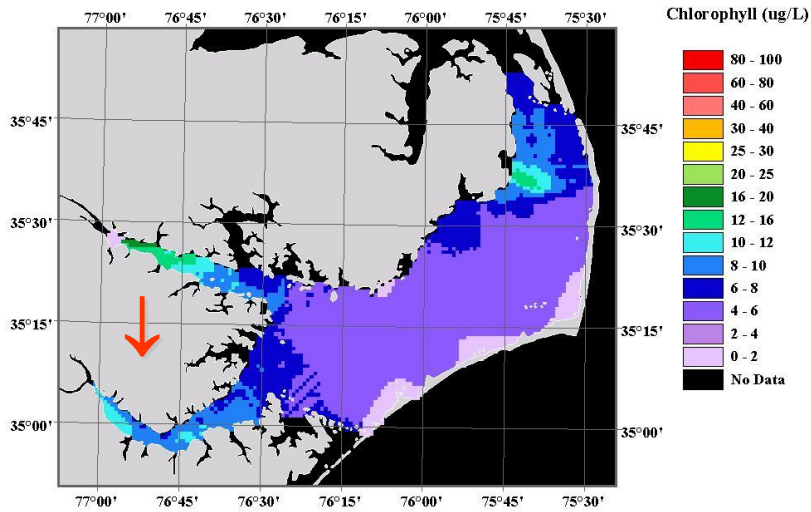


NASA / EPA Modified U2 Aircraft, Beaver LiDAR & SeaWiFS

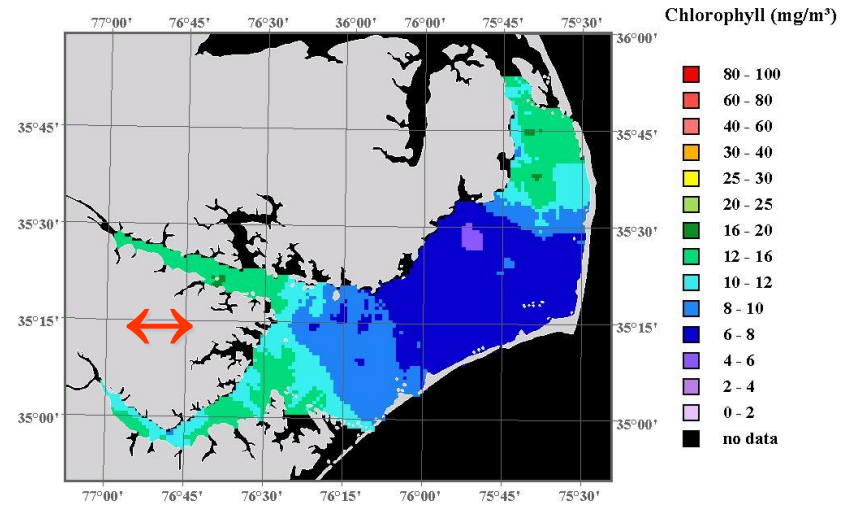


FerryMon/SeaWiFS: Freshwater Discharge effects on algal production (Chl *a*)

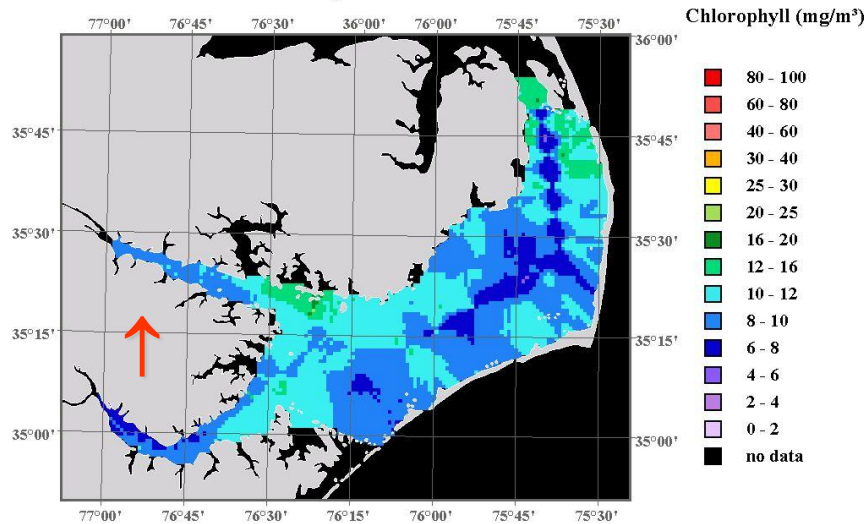
Pamlico Sound Remote Sensing Chlorophyll
15 May 2002



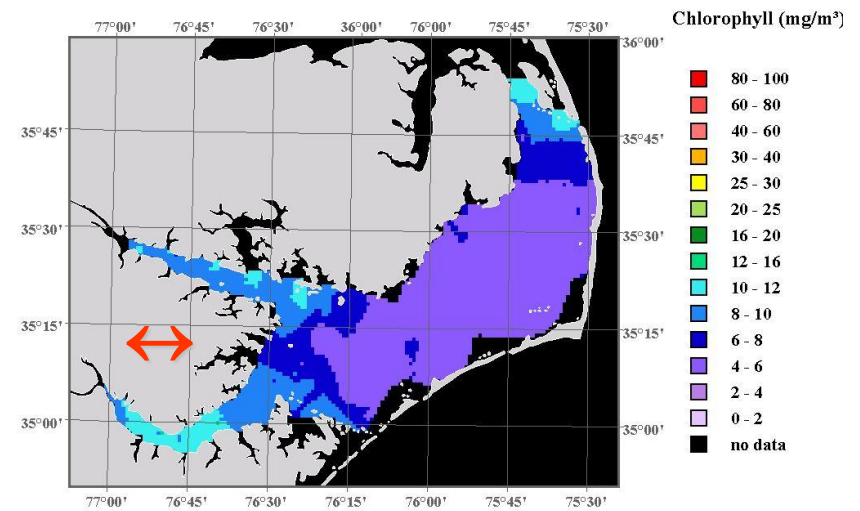
Pamlico Sound Remotely Sensed Chlorophyll
16 June 2002



Pamlico Sound Remotely Sensed Chlorophyll
17 July 2002

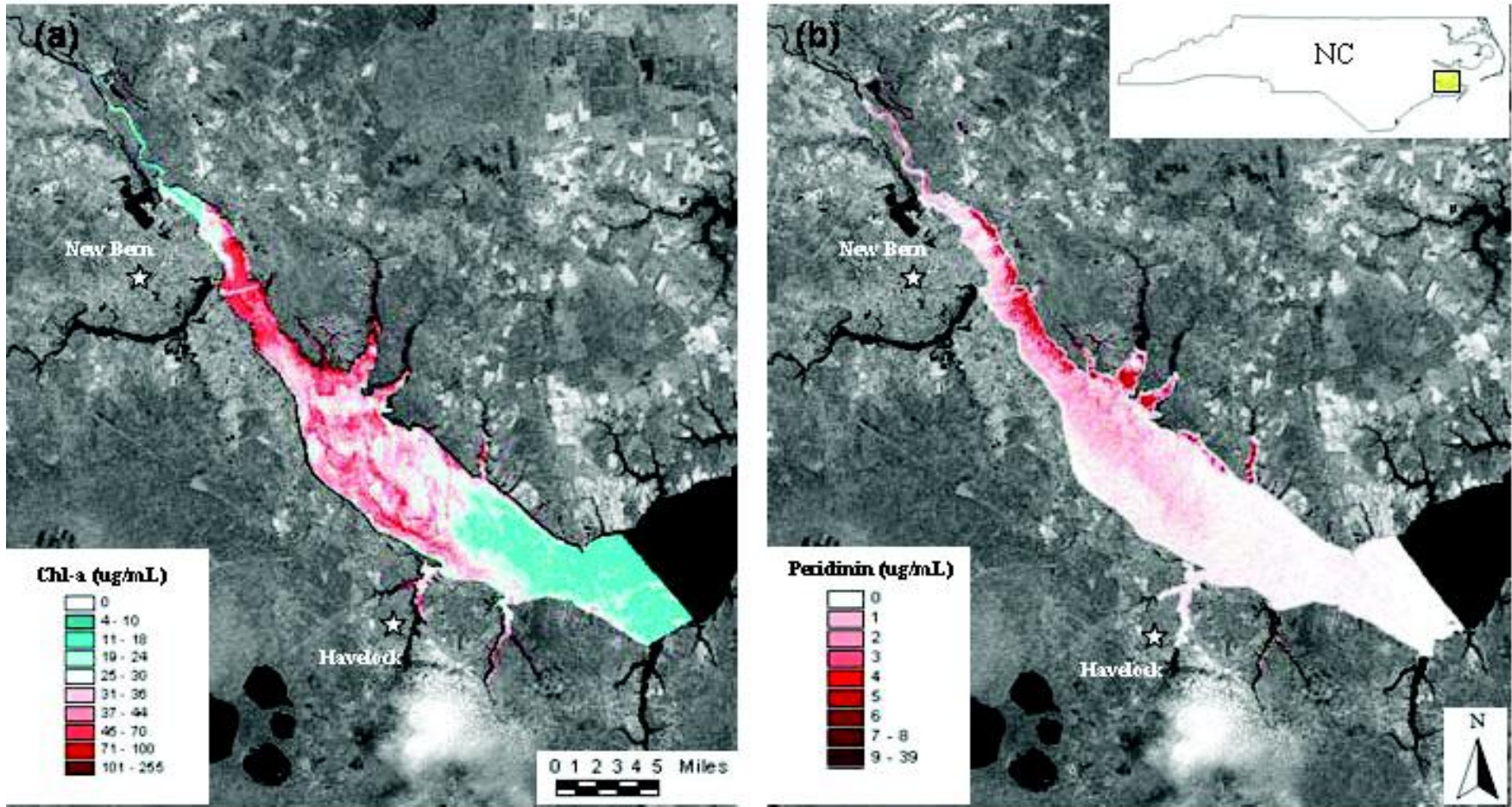


Pamlico Sound Remotely Sensed Chlorophyll
08 November 2002



Flow: high \uparrow , low \downarrow , moderate \leftrightarrow

Diagnostic Microalgal Indicators and Remote Sensing



Estimated Chlorophyll-a and Peridinin concentrations in the Neuse R. Estuary 15 May 2004 as determined with AVIRIS, FerryMon and ModMon data. (Lunetta et al 2009)

Users: EPA, NASA, NOAA, NC DENR-DWQ, Researchers

FerryMon data on the web: Weekly summaries

www.ferrymon.org



Pick a ferry route:

July 2007
S M T W T F S
 1 2 3 4 5 6 7
 8 9 10 11 12 13 14
 15 16 17 18 19 20 21
 22 23 24 25 26 27 28
 29 30 31

Select from the available years and months, then click on a linked calendar day to view data

2007 go

July go

Pick a ferry route:

July 2007
S M T W T F S
 1 2 3 4 5 6 7
 8 9 10 11 12 13 14
 15 16 17 18 19 20 21
 22 23 24 25 26 27 28
 29 30 31

Select from the available years and months, then click on a linked calendar day to view data

2007 go

July go

Current Conditions

This data can also be sent to you in an Excel spreadsheet format. Just email your data request to: data_request@unc.edu

Current Conditions

This data can also be sent to you in an Excel spreadsheet format. Just email your data request to: data_request@unc.edu

- what
- who
- where
- how
- why
- news
- current conditions
- educational resources
- publications
- contacts

- what
- who
- where
- how
- why
- news
- current conditions
- educational resources
- publications
- contacts

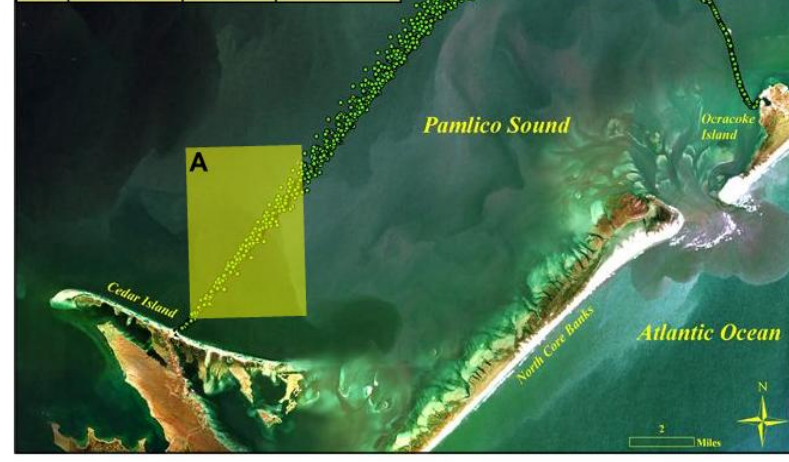
July 8 - July 14, 2007

A	Temperature (°C)	Salinity (ppt)	Chlorophyll a (µg/l)
Max	29.90	16.14	33.91
Min	27.36	11.61	4.11
Mean	28.43	13.66	9.53



July 8 - July 14, 2007

A	Temperature (°C)	Salinity (ppt)	Chlorophyll a (µg/l)
Max	29.77	22.74	4.61
Min	27.16	18.69	0.00
Mean	28.22	21.15	1.32



Data base: currently in MS Access-ArcGIS , GPS and time stamped

FerryMon: A Cross-Media, MultiScale Research and Management Tool



Thanks to:

Tim Boynton
Rodney Guajardo
Nathan Hall
Larry Harding
Alan Joyner
Ross Lunetta
Pam Wyrick

Buzzelli et al. (2003).
Estuaries 26:975-984.

Ensign & Paerl. (2006).
Limnol. Oceanogr. Meth.
4:399-405.

Paerl et al. (2009). ES&T
43:7609-13.



www.ferrymon.org

