The View from the COOLroom

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Rutgers University (R.U.)
Coastal Ocean Observation Lab (COOL)

Research
http://marine.rutgers.edu/cool

Education
http://coolclassroom.org

Public Outreach
http://www.thecoolroom.org
In Situ Research - ‘The Early Years’
Processes Operate of Time and Space

- CLIMATE
  - Decadal Oscillations/ Fish Regime Shifts
  - ENSO
- Mesoscale Phenomena
- Seasonal MLD & Biomass Cycles
- Coastally Trapped Waves
- Synoptic Storms, River Outflows, & Sediment Resuspension
- Internal Tides
- Surface Tides

Time Scales:
- 100 years
- 10 years
- 1 year
- 1 month
- 1 week
- 1 day
- Diurnal
- 1 hour
- 1 min
- 1 sec

Horizontal Spatial Scales:
- 1 mm
- 1 cm
- 1 dm
- 1 m
- 10 m
- 100 m
- 1 km
- 10 km
- 100 km
- 1 km
- 1,000 km
- 10,000 km

- Molecular Processes
- Individual Movement
- Turbulent Patch Size
- Langmuir Cells
- Inertial/Internal & Solitary Waves
- Surface Waves
- Plankton Migration
- Phytoplankton Blooms
- Fronts, Eddies & Filaments
NATURAL VARIABILITY: Where do you put a mooring? Where do drive the ship? When should I be out there?

Color variability at multiple scales around Tasmania from CZCS image

Causes? Strong winds, strong currents, bottom topography, etc.

Thanks Mossian (NASA) and Wilkins (Rutgers)
Technology will make life good
My Lab
A Coastal Observatory: 1993

Continuous Sampling on the New Jersey Shelf Began in 1993
A field station & an environmental impact report
LEO 15 Fiber Optic Cable
11 tons, 10 km
Sediment Transport Studies at LEO Site – early 1990’s

Benthic Acoustic Stress Sensor (BASS) Tripod
Before and After Summer Deployment at LEO
BASS Tripod
For LEO-15
Late 1990’s
Lesson: The importance of having a continuous picture to the sea
Optical profiler deployed on LEO-15 guest port

Tidal cycle

Upwelling

Absorption at 440 nm (m⁻¹)
Satellite Data Acquisition Systems

- US MODIS
- India Oceansat
- China FY1-D

[Images of satellite data acquisition systems for 1992 and 2003]
Satellites (Spatial view of what is in the water)

- **A)** Broad view of global water bodies with varying colors indicating different conditions.
- **B)** Detailed view of a specific region, possibly focusing on a coastal or transitional zone.
- **C)** Close-up view highlighting specific features, possibly showing depth or CDOM (Color Dissolved Organic Matter).
- **D)** Another perspective or zoom level, showing different shades and patterns.
- **E)** A text area labeled with a CDOM range (0.20 to 0.40), indicating a measure of organic matter in the water.

**Depth (m)**: A scale is present, indicating depth measurements from 0 to 12 meters, with Julian Day as the time axis from 202 to 214.
New Enabling Technologies – CODAR HF Radar

Each Radar Measures Radial Component of the Surface Current

Hudson Plume – April, 2005

Summer Storm – July, 2005
British 25-MHz "Chain Home" built 1938 to detect German bombers
"Bragg" sea echo from English Channel mistakenly labeled "jammer"
These systems preceded microwave radars by several years
Microwave vs. HF -- what's the difference?: (about three orders of magnitude!)

Example: 500-m half-rhombic array built by DoC (Barrick) in 1972 -- SCI, CA

But Why HF?
Beyond the horizon

Scatter from water waves is simple

2 billion microwave radars exist

Only 350 HF radars exist in the world, 300 done by CODAR

HF radars not good for much except sea scatter & ships
What does an HF RADAR consist of?

- Computer and Monitor
- Transmitter
- Receiver
- Transmit Antenna
- Receive Antenna
- Electronics
- Monopole (A3)
- Loop box (A1 & A2)
- Radial whips
Ground Wave Propagation & Depth of Measurement

- Requires interface between free space (air) and highly conductive medium (>8 ppt salinity sea water)
- Ocean surface exists as a free boundary allowing surface molecules freedom to conduct EM energy, much like a waveguide
- Allows vertically polarized EM energy to propagate w/ reduced energy loss for greater distances and beyond horizon
- Radar wave does not penetrate surface at all - depth of measurement comes from effective depth-averaged current “felt” by ocean wave
- 25 MHz measures to < .5 m, 5 MHz measures to 2 m deep

Air is almost like free space

Seawater is conductive

Depth of measurement is related to ocean wavelength (Can be linear or logarithmic)
Bragg Sea Echo

<table>
<thead>
<tr>
<th>Freq (mhz)</th>
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<th>λ/2 (meters)</th>
<th>T (seconds)</th>
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SeaSonde Principles
Bragg Sea Echo

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SeaSonde Principles
Bragg Sea Echo

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Two (or more) Sites Used to Produce Total Current Vector Maps from Single-Site Radials Where Coverages Overlap

Angle of incidence Greater than 15° or less than 165°
Nested Standard Range Network
Radial Coverage

Total Coverage

MONTHLY COVERAGE
Jul 2009

MISSING DATA FROM 7/2009
Radial Coverage

Total Coverage

MONTHLY COVERAGE
Oct 2009
Every Other Vector Shown for Plotting Purposes

Temporal Coverage Greater than 50% Required for Plotting

DEC 2008 to NOV 2009
Winter  DEC ‘08 – FEB ‘09

Spring  MARCH ’09 – MAY ‘09
Summer  JUNE ’09 – AUG

Fall    SEPT ’09 – NOV

Latitude

Longitude
Every Third Ellipse Shown for Plotting Purposes

Temporal Coverage Greater than 50% Required for Plotting
24 Hours Into Search

HYCOM
Low Confidence

HF Radar
High Confidence
48 Hours Into Search

HYCOM
Low Confidence

HF Radar
High Confidence
Search Area After 96 Hours

HYCOM
36,000 km²
10,500 nmi²

HF Radar
12,000 km²
3,500 nmi²
What do the subsurface remote sensing platforms look like?

**Large and medium-sized AUVs**

- Autosub
  - Southampton Oceanography Centre
  - Martin-600
  - Maridian, Denmark

- Hugin
  - Kongsberg Simrad, Norway

- Explorer family
  - ISE Research, Canada

- Odyssey
  - Bluefin Robotics, USA

Thanks to Gwynn Griffiths
What will the subsurface remote sensing platforms look like?

AUVs do not need to be large ...

Thanks to Gwynn Griffiths
Range of space and time regions can be covered effectively.
Oceans are complex and hard to sample: Small scale variability

Ship Sampling for Bioluminescent Photons

Robot Sampling for Bioluminescent Photons

Thanks to Marine

1E10 bioluminscent photons/s

3E10 bioluminscent photons/s
2) Coastal Processes Study

Scaling issues between:
- Discharge jet
- Offshore advection
- Surfzone mixing – wave driven transport

• DELFT 3D being used to test interplay between momentum of discharge jet, width of breaking and strength of wave driven currents in surf and width of surfzone, and offshore transport

• Model runs showing
Example of mapping a freshwater plume out of the Tijuana River. Plume moving north. Salinity on left, optical scatter (turbidity) on right. Mapped with REMUS 100 – HF RADAR Surface currents used for mission planning.
Slocum Coastal Glider

Glider Specs.
Length: 1.5 m Hull Diameter: 21.3 cm
Weight: 52 kg

Science Bay Specs.
Length: 30 cm Diameter: 21.3 cm
Max. Payload Weight: 4 kg
A YEAR IN THE LIFE OF THE MID-ATLANTIC BIGHT

Oct. 03

Nov. 03

Nov. 03

Dec. 03
03-Dec-2003 18:05:17 - 12-Dec-2003 15:35:37

Jan. 04
14-Jan-2004 18:32:09 - 20-Jan-2004 05:19:02

Jan. 04

Feb. 04

Feb. 04
26-Feb-2004 20:10:30 - 03-Mar-2004 05:11:02

Mar. 04

Mar. 04

Apr. 04

Apr. 04

May. 04

May. 04

Jun. 04

Jun. 04

Jun. 04

Jul. 04
04-Jul-2004 02:36:44 - 09-Jul-2004 07:19:43

Aug. 04

Sep. 04
16-Sep-2004 15:00:53 - 23-Sep-2004 11:57:27

Oct. 04
Science Findings

A) Storms lead to massive resuspension in the winter and early spring. After summer stratification, storm induced mixing rarely mixes particles through the strong MAB pycnoclines, but lift material to the pycnocline base.

B) Particles accumulate in the cold pool and then are advected back to shore in the summer.

C) Particle distributions are best described by haloclines on the MAB.
Rutgers, Webb Research, and Instrument Companies Spiral Development Cycle

- Inception
- Elaboration
- Construction
- Transition

Design → Develop → Iterate → Deploy

Validate → Test → Refine → Promote

Images of various underwater equipment and tools are shown on the right side of the page.
Gliders will be used to assist numerous applied mission planning and simultaneously provide the first subsurface network capable of enabling ecosystem management.
Gliders will be used to assist numerous applied mission planning and simultaneously provide the first subsurface network capable of enabling ecosystem management.

How we fund the sensor integration

MISSION PLANNING
MCM, acoustic propagation

MISSION PLANNING
MCM, DIVER, Luminescence detection

MISSION PLANNING
Food webs, “Bio-clutter”

ECOSYSTEM MANAGEMENT MODELS
External Modular Sensors
Oregon State University Collaboration
ChiPod attached to glider for 1 and 18 day missions
The ability to map space persistently at sea is key: Here 4 gliders changed Naval tactics during a submarine war game 64 times in 1 month.
Gliders will be used to assist numerous applied mission planning and simultaneously provide the first subsurface network capable of enabling ecosystem management.
RIVERS
NSF’s LaTTE – Under transports and transformations of Hudson River Plume
Light: ONR’s OASIS experiments at Martha’s Vineyard (spectral downwelling irradiance, and the apparent optical properties)

**Ed491 (nm)**

**Kd491 (nm)**
Phytoplankton: ONR’s HyCODE & OASIS and NSF’s EcoHAB programs (bulk phytoplankton and phytoplankton composition)

Phytoplankton response to passage of Nor’Easter storm

Phytoplankton biomasses

Phytoplankton communities
Sediment: ONR’s OASIS and MIREM programs focused on refining understanding of nepheloid layers and importance of storms. Empirical algorithms.
Detritus: With the availability of hyperspectral absorption invert the detrital optical load using techniques developed for ac-9 (ONR HyCODE)
ONR MIREM experiments: The combination of optical parameters can be used to define optically-based mission planning models.

The Problem: What can you see?
Helicopter or diver….

**April 24, 2005**

Clear water

Real water

**April 26, 2005**

Clear water

Real water

Towed MCM detection system

Red = poor detection

Probability of detection at an altitude of 10m off bottom.
Gliders will be used to assist numerous applied mission planning and simultaneously provide the first subsurface network capable of enabling ecosystem management.

How we fund the sensor integration

MISSION PLANNING
MCM, acoustic propagation

In situ Acoustic Field

2nd and higher trophic levels

actual water column physics

mixing

weather

Mean water column hydrography

phytoplankton

CDOM

sediments

detritus

rivers

light

nutrients

optical properties

How we fund the sensor integration

MISSION PLANNING
MCM, DIVER, Luminscence detection

MISSION PLANNING
Food webs, “Bio-clutter”
NOAA OE & NJ DEP: The production of CDOM & detritus tightly coupled to phytoplankton growth; therefore there is need to measure growth and metabolism.
Gliders will be used to assist numerous applied mission planning and simultaneously provide the first subsurface network capable of enabling ecosystem management.
• June ’06 URI visits Rutgers with hydrophone
• August ’06 Hydrophone attached to glider for 15 minute segment
• Sept. ’06 Hydrophone attached to glider for 14 day mission
• April ’07 URI visits Rutgers for two days of experiments to test beam forming capability

Final configuration with hydrophone towed behind glider with no rigid connection between the two

Future focus areas will be on recording marine sounds with specific focus on higher trophic levels.
External Modular Sensors

NOAA National Marine Fisheries Service (NMFS) Collaboration

Vemco “Fish Finder” Attached to glider for 1 and 12 day missions

160 Acoustic pings from transmitter over 2 hour period
Currently gliders are being outfitted with RDI Explorer ADCP, focus on currents, bottom tracking and zooplankton

1) The sensor

![TRDI Explorer DVL](image1)

<table>
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<tr>
<th>Bottom Tracking</th>
<th>Phased Array</th>
<th>Piston</th>
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<tr>
<td>Maximum Altitude</td>
<td>75m</td>
<td>65m</td>
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<tr>
<td>Minimum Altitude</td>
<td>0.5m</td>
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<tr>
<td>Velocity Range</td>
<td>± 5 m/s</td>
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<tr>
<td>Long Term Accuracy</td>
<td>± 0.4% ± 0.2 cm/s</td>
<td>± 1.2 cm/s</td>
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<tr>
<td>Precision @ 1 m/s</td>
<td>0.1 cm/s</td>
<td>0.01 cm/s (selectable)</td>
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<tr>
<td>Ping Rate</td>
<td>7 Hz Typical</td>
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<table>
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<th>Water Profiling</th>
<th>Maximum Range</th>
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<td>Minimum Range</td>
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<td>Long Term Accuracy</td>
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<td>Precision @ 1 m/s</td>
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<tr>
<th>Acoustic</th>
<th>Sound Pressure Level</th>
<th>213 dB re 1 uPa @ 1 m</th>
<th>205 dB re 1 uPa @ 1 m</th>
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<tr>
<td>1-Way Beam Width (Typical)</td>
<td>2.4°</td>
<td>3.3°</td>
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<tr>
<td>Center Frequency</td>
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<td>Number of Beams</td>
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<td>Beam Angle</td>
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<th>Environmental</th>
<th>Maximum Operating Depth</th>
<th>100 m</th>
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<td>-5°C to 40°C</td>
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<td>Storage Temperature</td>
<td>-25°C to 60°C</td>
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<td>IEC 60721-3-2, 2nd Ed, 1997-3</td>
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<td>IEC 60945, 4th Ed, 2002-8</td>
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2) Expanded glider payload capacity

320 Alkaline C-cells versus 230
Month Long Experimental Effort

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<tr>
<th>Sun</th>
<th>Mon</th>
<th>Tues</th>
<th>Wed</th>
<th>Thurs</th>
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<td>Forecast Cycle 8</td>
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<td>Briefing</td>
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Atmosphere/Ocean Physical/Biological Forecast Models

- Operational Low-Res COAMPS Atmospheric Model
- Experimental High-Res RAMS Atmospheric Model
- Air-Sea Interaction Model
- ROMS Ocean Model (KPP and MY 2.5 Turbulent Closure)
- Bottom Boundary Layer Model

ROMs Assimilation
MODAS Assimilation
2001 Real-time Ensemble Forecasts
Atmosphere/Ocean Physical/Biological Forecast Models

- Operational Low-Res COAMPS Atmospheric Model
- Experimental High-Res COAMPS Atmospheric Model
- Air-Sea Interaction Model
- ROMS Ocean Model (KPP and MY 2.5 Turbulent Closure)
- Bottom Boundary Layer Model
- 3-D visualization
- Forecast Briefing
- Hindcast Models
  - EcoSim Bio-Optical Model
How well can we sample a 20 by 20 kilometer box in the ocean?
Hypoxia/Anoxia & Bottom Bathymetry

Historical Recurrent Hypoxia Centers

Depth
- 12 m
- 15 m
- 20 m
- 25 m
- 30 m
- 35 m
- 40 m
- 50 m
- 100 m
- 500 m
- 1000 m
- 2500 m

Warsh – NOAA 1989

Long Island

New Jersey

Field Station

Barnegat

LEO

Cape May

74 W

73 W

40 N

39 N
New Jersey Coastal Upwelling

July 6, '98 - AVHRR

Temperature °C
19 20 21 22 24

July 11, '98 - SeaWiFS

Chlor-a (mg/m³)
.1 .3 .5 1 2 4

Historical Hypoxia/Anoxia
Field Station

Barnegat

Cape May

Field Station

LEO
Figure 6

Song et al (JGR) 2002
30 X 30 km LEO CPSE
An Integrated Observatory
- In an observationally rich environment, ensemble forecasts can be compared to real-time data to assess which model is closer to reality and try to understand why.
Optical profiler deployed on LEO-15 guest port

Depth (m)

Time (hr)

Absorption at 440 nm (m⁻¹)

Tidal cycle

Upwelling

0

30

60

0

1.0
Shipboard surveys
Adaptive Sampling of Resolved Scales - Shipboard & AUV surveys

North Fluorometer

North Velocity

Surface Towed-ADCP Velocity Section: Date 980723, Leg 03

South, offshore flow
That Pristine Blue NJ Water
POC represents potentially 182 µmol oxygen/kg
Upwelling can account
For spatially distribution
of recurrent upwelling eddies

-Where does the POC come from?
  What is the annual particle dynamics for the shelf itself?
  How important is are rivers in the loading of material?
-What regulates “big upwelling years”
  The big upwelling years seem to follow colder winters
  is it the size and extent of the Mid-Atlantic cold pool?
New Jersey Shelf Observing System (NJ-SOS)

Satellites, RADAR, Gliders

300 X 300 km NJSOS
An Integrated & Sustained Observatory

http://marine.rutgers.edu/cool

Satellites, RADAR, Gliders
Where we do go from here?
Welcome to the Rutgers University Institute of Marine and Coastal Sciences Marine Remote Sensing Lab

Real Time/Archived Data

Sea Surface Temperature Images - SSTs from the Entire East coast of the USA

Visible Satellite Images - Visible Images of the Entire East coast of the USA

Vegetation Production Images - Vegetation Productivity of the Entire East coast of the USA

Lab Info.

Real Time Data:
- Image Collection
- Met. Data
- LEO 15 Data

Research:
- LEO 15
- North Atlantic
- Gulf Stream

Upwelling:
- Sediment Transport
- MAB-NURC
- Natural Disasters

Links

White Pages
How do we archive and distribute the data?

**Initial data distribution**
- Duck Field Research Facility model.
- Monthly reports summarizing the data on an FTP site.

**A new approach to data distribution**
- Keith Bedford (Ohio State University) approached us with a concept known as the “world wide web”.
- He claimed he could get 30 hits a month!
OUTREACH

Rutgers COOL Web Site Hits

Average Hits Per Day

Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

Chart showing the average hits per day for the Rutgers COOL Web Site from January to December, with data for different years represented by different line colors and symbols.
Rutgers Web Site Statistics

**Data Type**
- SST 53%
- CODAR 13%
- NODES 13%
- MET 17%

**Region**
- MAB 28%
- NYB 37%
- Gulf Stream 10%
- LEO 6%

**Other**
- General Public 69%
- Non-profit (7%)
- Education (6%)
- Military & Government (4%)

**By Hour**

Average Hourly Hits

- June
- July
- August
- September
- October
- November
- December
- January

Average Hourly Hits 0:00 to 21:00
Ship-to-Shore Communications

- **AirNet Communications Wireless Broadband** (~1.5 Mbps, coverage 7 miles offshore from Sandy Hook)
- **Verizon National Access** (~100 kbps, coverage up to 20+ miles off Long Island, less for New Jersey)
- **Freewave Radio Modems** (~80 kbps, coverage for a 18 mile radius centered at Sea Bright Fire Department)
- **Verizon Quick2Net** (14.4 kbps, coverage up to 20+ miles off both New Jersey and Long Island)
- **Iridium Satellite** (2,400 bps, global coverage, data and voice)
Hypoxia/Anoxia & Bottom Bathymetry

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New Jersey

Warsh – NOAA 1989

Long Island

River? upwelling?

upwelling

LEO

Field Station

Barnegat

Cape May
RIVERS ARE IMPORTANT TO THE OVERALL SHELF BUDGET OF CARBON AND BIOLOGICAL PRODUCTIVITY. HOW DO WE DISCRIMINATE RIVERS?
ANNUAL CHLOROPHYLL A FOR THE MAB

Mean River Chlorophyll

Mean Shelf Chlorophyll

Mean Coast Chlorophyll

Pie Chart: river 25%, shelf 51%, coast 25%
Science focus Land-Ocean: How does the dynamics in the physical oceanography influence the transport and transformation of the particulate and dissolved matter in coastal buoyant plumes?

Downwelling

Upwelling

Southern flowing turbid plume

Eastern offshore flowing shallow turbid plume

Geyer and Fong
Downwelling condition

Downwelling condition

05-May-2004 11:33:11 - 06-May-2004 01:14:01 (GMT)

-73°54’ -73°52’ -73°50’ -73°48’ -73°46’ -73°44’

10 20 30 40


-73°54’ -73°52’ -73°50’ -73°48’ -73°46’ -73°44’

0 10 20 30 40

Upwelling condition

The Geyer-Fong plume dynamic appears to hold HOWEVER......
CARBON IS PROVIDED TO THE SHELF FROM NUMEROUS RIVERS FED BY BIG WATERSHEDS

- Estuary Exit
- Near-Shore
- Shelf
Input of organic matter is pulsed to coastal system as floods and punctuated tidal squirts. Example, a tidal bore as it flows past the R/V Cape Hatteras
Wind data from NOAA NDBC station at Ambrose Light
Wind data from NOAA NDBC station at Ambrose Light
Wind data from NOAA NDBC station at Ambrose Light
Wind data from NOAA NDBC station at Ambrose Light
Wind data from NOAA NDBC station at Ambrose Light
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Wind data from NOAA NDBC station at Ambrose Light
WHAT FLOWS OUT? PARTICLES AND DISSOLVED ORGANIC MATTER

Temperature

Salinity

c532(nm)

b532/c532

bb532(nm)

CDOM Fluorescence

Depth

Longitude
The Nearshore Recirculation: A Remineralization Incubator
(known to locals as the Frazer eddy)
The graph shows productivity (mgC/m^3/hr) over different dates for both New Plume and Old Plume.

- **New Plume**:
  - Productivity values: 10, 12, 14, 15

- **Old Plume**:
  - Productivity values: 5, 3, 2

The graph also indicates the percentage of carbon fixed by different size fractions:

- **% carbon fixed**
  - > 20 um
  - 2 - 20 um
  - < 2 um

Microscopic images show the presence of Thalassiosira, Stephanopyxis sp., and Skeletonema.
Grazing rates in Hudson river plume

You can’t eat things bigger than your head

Density of mesograzers

Change in Chl a (ug/L; 24h)
>20 µm particulate trace metals and phosphorus - Ag, Al, Cr, Cu, Fe, P, Pb

50 ng L$^{-1}$
(Al, Fe, P µg L$^{-1}$; Ag x 10, Al x 5, P x 10)
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Field Station
Barnegat
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Cape May
Freshwater Plume Moves Out Across the Shelf: Hudson Shelf Valley
“The survey began on the 'Highway'. We were near the glider when it surfaced. We saw currents ripping southward in a 10 m thick layer of freshwater along the highway -- perhaps the most significant freshwater transport we saw all week.”

“Perhaps the most perplexing to me is 'the Highway' and why there has been a lack of a strong coastally trapped flow this week.”

--- Bob Chant aboard the Cape Hatteras, April 21, 2005
Freshwater Plume Moves Out Across the Shelf: Water Mass Boundaries
( Oliver et al., 2004)

April 13, 2005

-NJ highway transports carbon, fish larvae, etc.
Seaward of the edge
Shoreward of the edge
Plume Edge
Sea floor

04-May-2004 16:13:26 - 10-May-2004 10:30:08 (GMT)
Seasonal Climatologies

Annual mean 2002

Annual mean 2003

Summer mean 2002-2003

Winter mean 2002-2003
Frequency of Fronts
February 1985-1990

Thanks to Dave Ulman
Rutgers Coastal Observatory
Provide a Long-term Shelf-Wide Context for High Resolution Nested Process Studies
Dawn in the age of observatories

“I walk into our control room, with its panoply of views of the sea. There are the updated global pictures from the remote sensors on satellites, there the evolving maps of subsurface variables, there the charts that show the position and status of all our Slocum scientific platforms, and I am satisfied that we are looking at the ocean more intensely and more deeply than anyone anywhere else.” Henry Stommel

Lessons learned:
1) It takes years to build an integrated observing network, good plan is to set aside ~ 5 yrs.
2) Pay-off is worth it, however waiting for maturation can be slow,
3) Pay-off is discovering unexpected things
4) Pay-off is going to sea EVERY day

THANK YOU