Land/Ocean Biogeochemical Observatory: A real-time chemical sensor network for complex environmental systems

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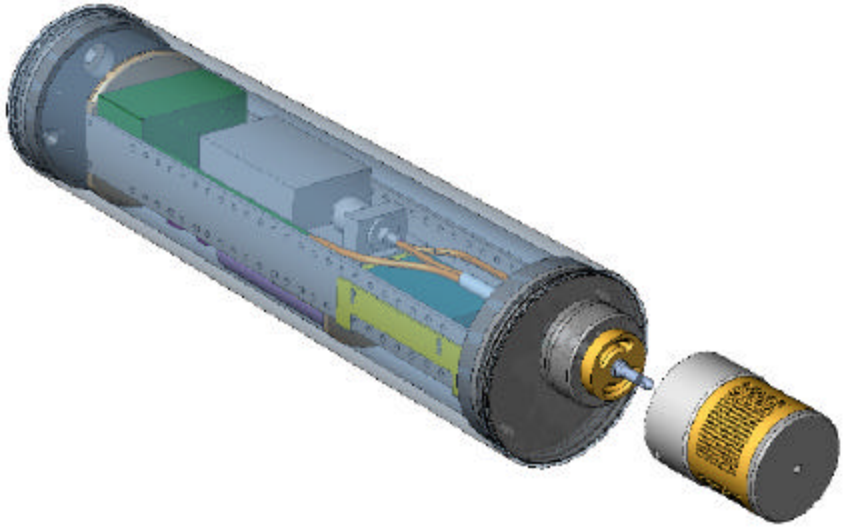
Monterey Bay Aquarium Research Institute



Addressing major questions in aquatic biogeochemistry will require extended chemical sensor arrays that operate at global or ocean-basin scales:

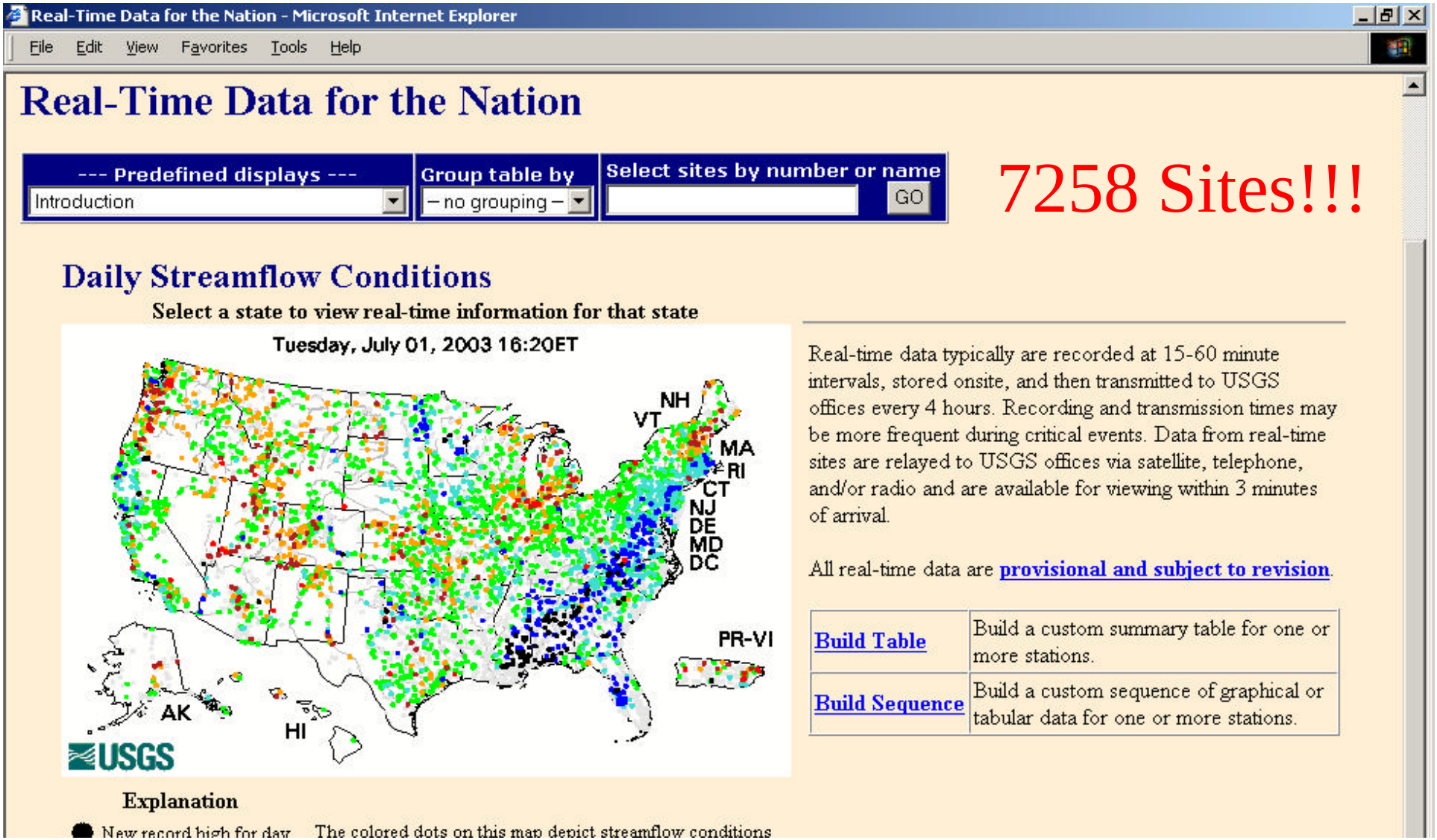
Biogeochemistry & Climate:

- What is the new annual primary production of the ocean? How does it change as climate warms?
  - There are not enough ships and scientists to measure this directly. Satellites don't observe the ocean interior.
  - It could be observed directly with large networks of chemical sensors for oxygen distributed throughout the ocean.

Biogeochemistry & Man's Activity in the Coastal Zone

- What is the flux of nitrate from land to coastal waters? What is the impact on coastal ecosystems – Dead Zones?
  - Production of fixed nitrogen (fertilizer) now exceeds natural levels of production.
  - Sensors for nutrients now exist – can we operate large enough arrays?

How big are these arrays? Look at comparable systems. For example, what does it take to monitor fresh water flows? Would a nitrate flux monitoring system be more or less complicated? If the required scale is comparable, we need very robust sensors!



Goals of the Land/Ocean Biogeochemical Observatory (LOBO) Project

- Design and operate an autonomous network of chemical sensors to study the biogeochemistry of complex coastal environment.

- Demonstrate the potential of an extended chemical sensor networks to significantly improve our observational capabilities and advance our understanding of ecosystem biogeochemistry.

Goals of the LOBO Project

- Demonstrate an economy of scale for chemical sensors: 10 sensors ≠ 10 postdocs!!!

Measurements on the LOBO moorings:

Nutrients: NO_3^-, NH_4^+, PO_4^{3-}

Biological Properties: O_2, Chl *a*

Water properties: Salinity
Temperature
Turbidity

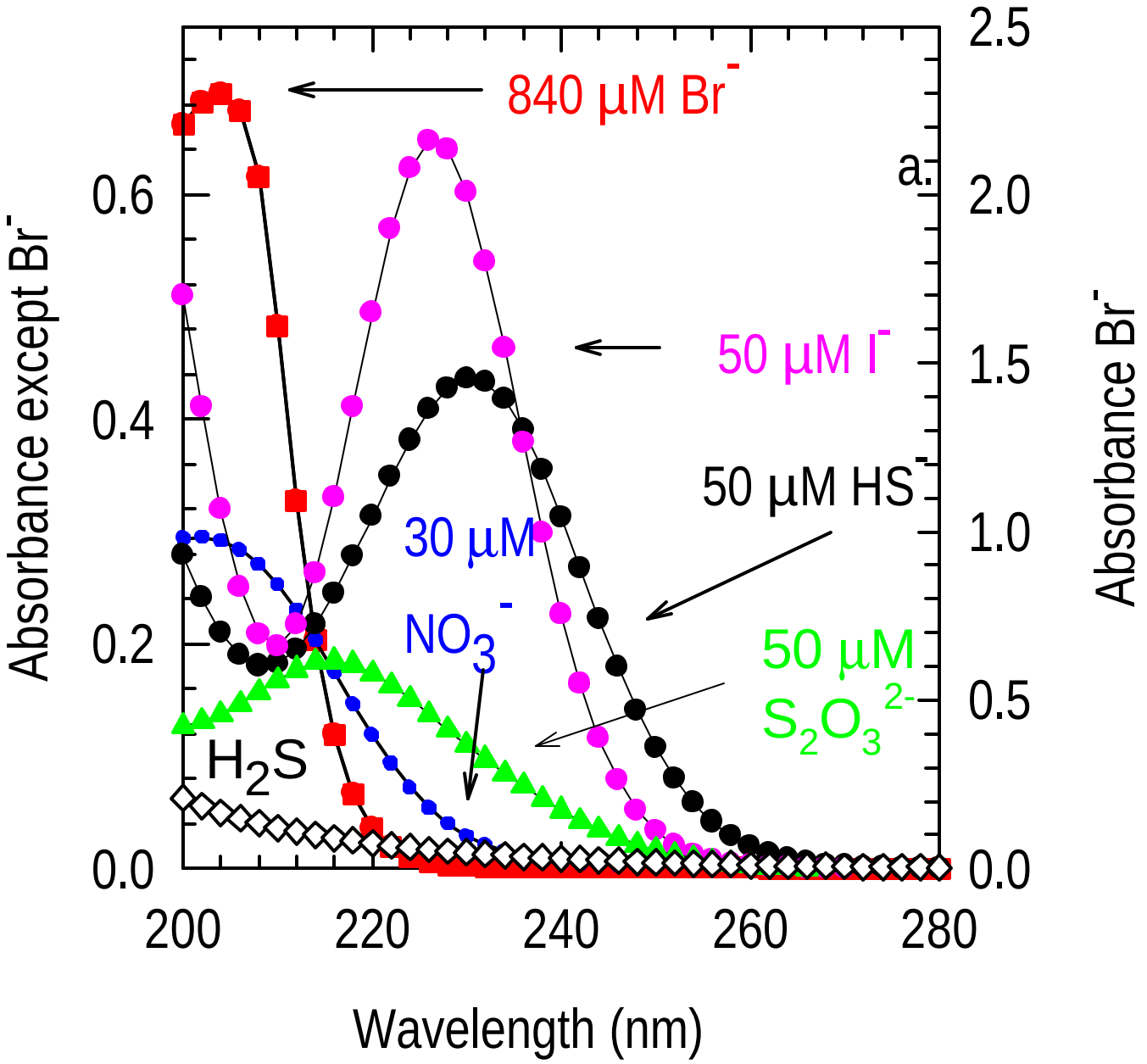
Tidal cycle: Water Depth

Currents: Water Velocity

AVIRIS photo courtesy of John Ryan, MBARI

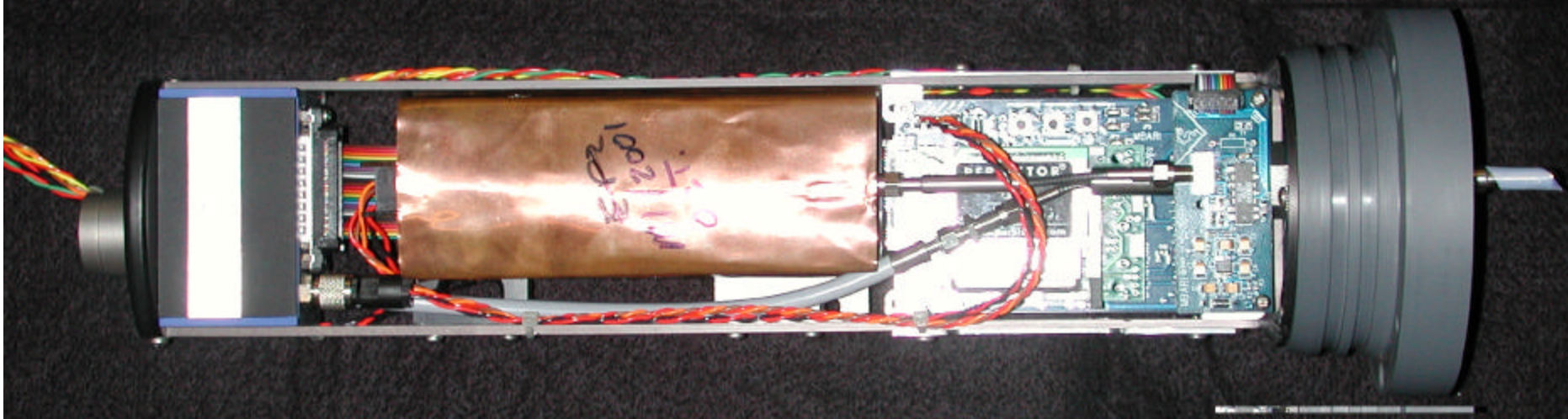
Photo courtesy of Todd Walsh

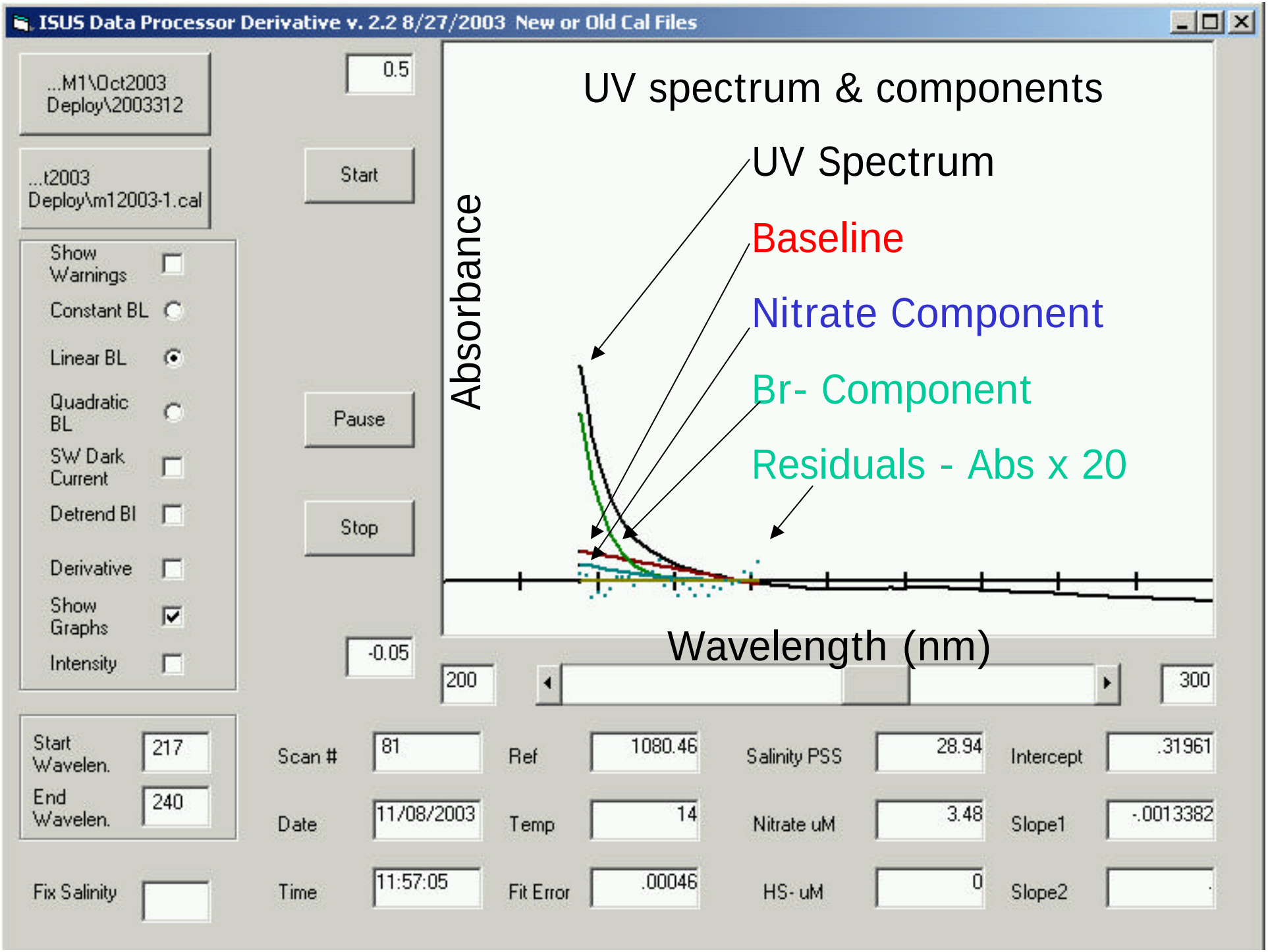
Advances in opto-electronics now make it possible to measure nitrate and bisulfide directly in seawater using their UV absorption spectrum (Johnson and Coletti, 2002).



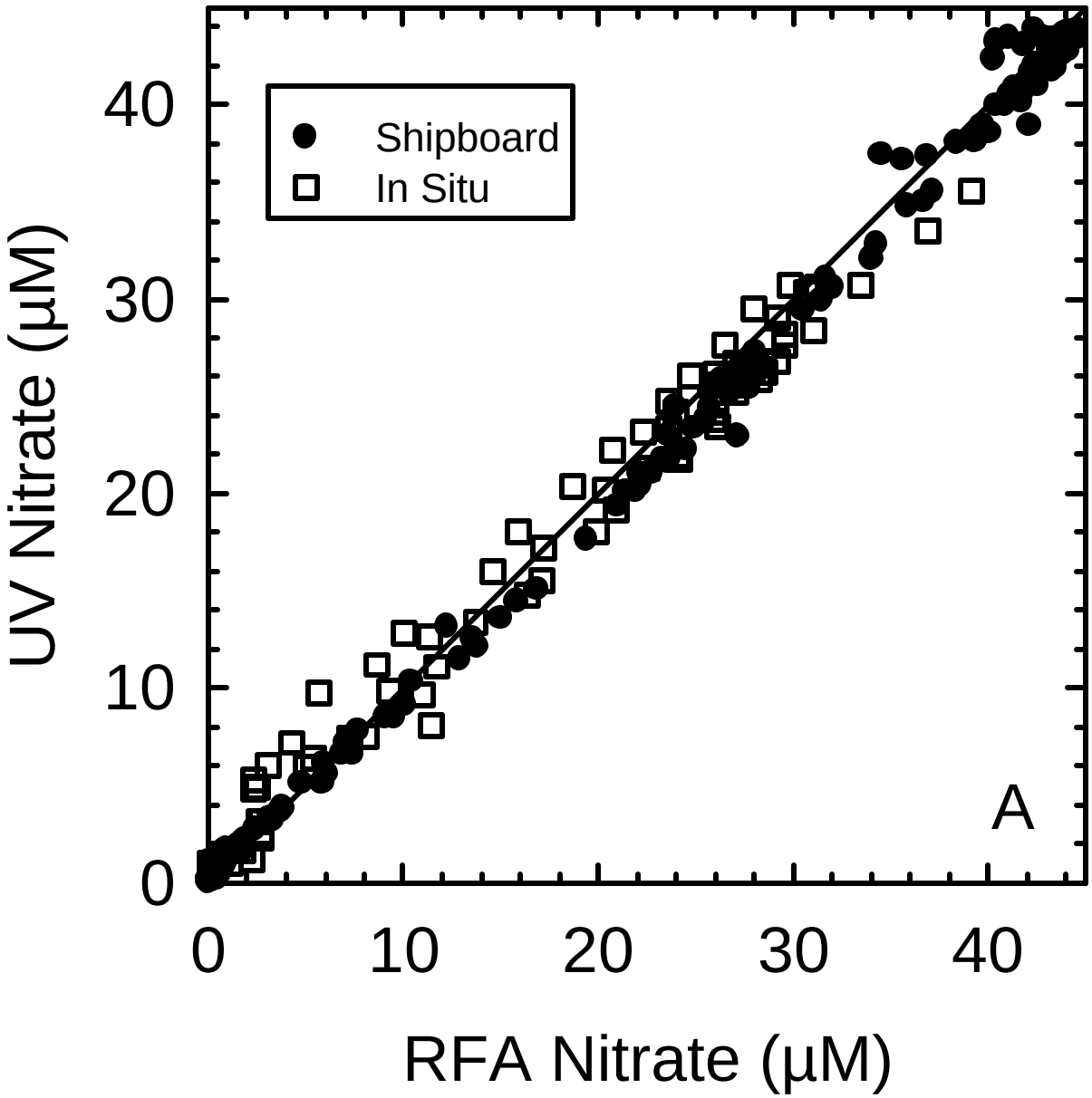
In Situ Ultraviolet Spectrophotometer

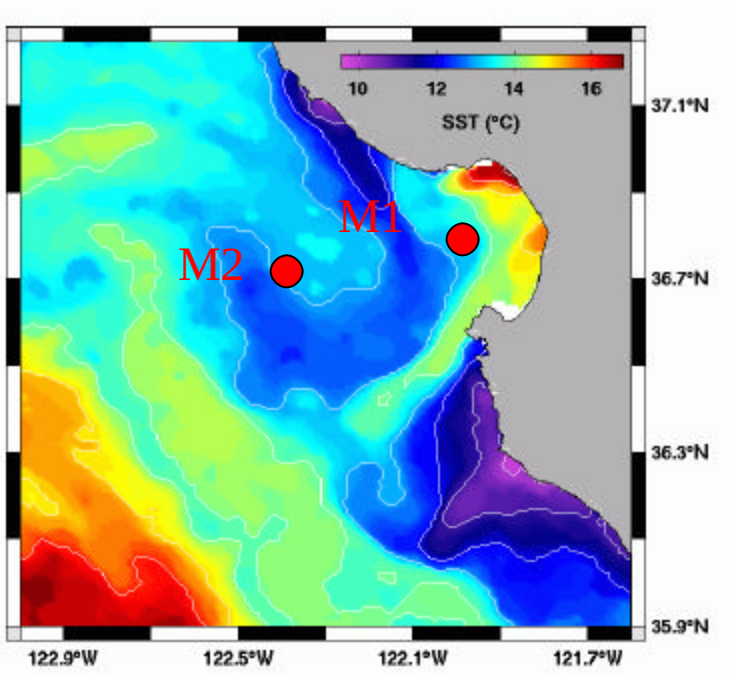
commercially available as Satlantic MBARI ISUS

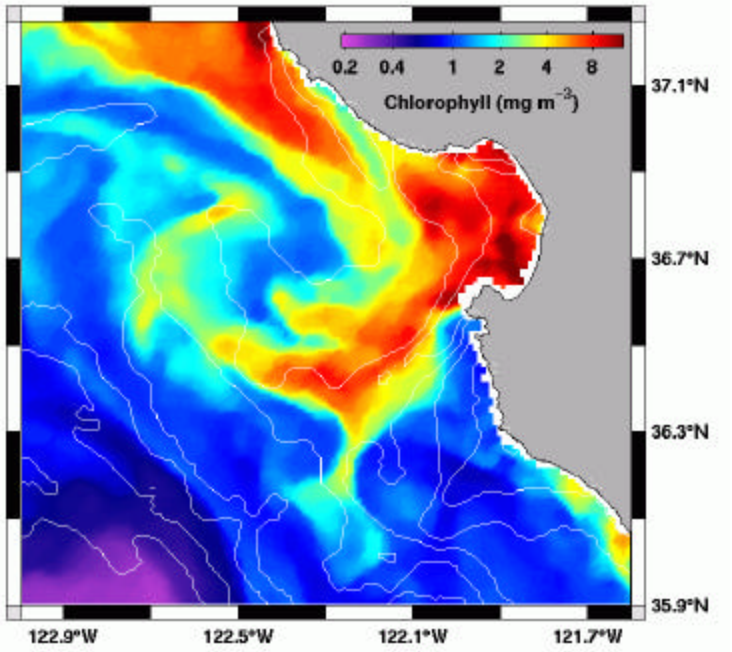


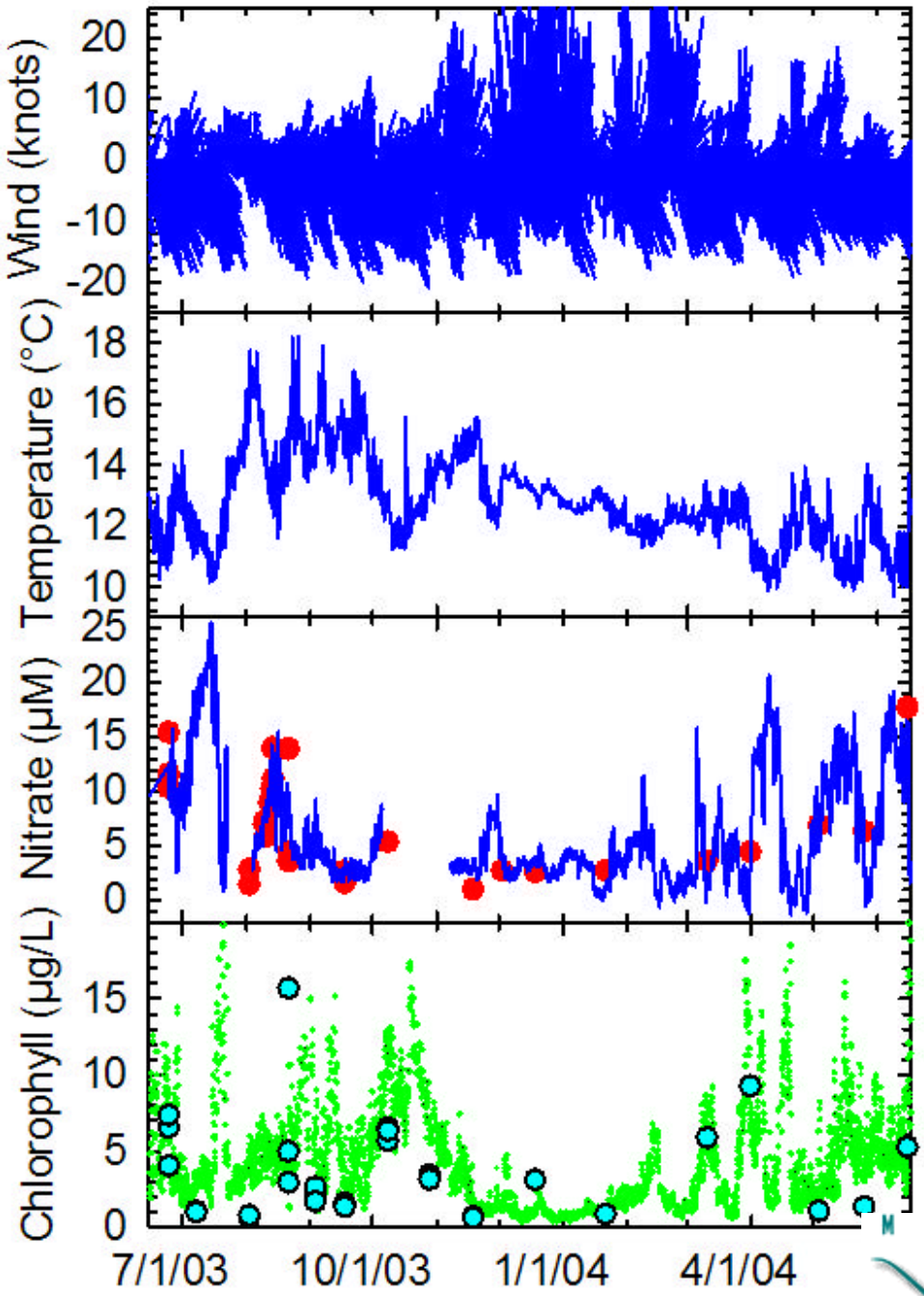

ISUS Data Processor Derivative v. 2.2 8/27/2003 New or Old Cal Files
...M1\Oct2003 Deploy\2003312
...t2003 Deploy\m12003-1.cal
0.5
Start
Pause
Stop
-0.05
Show Warnings
Constant BL
Linear BL
Quadratic BL
SW Dark Current
Detrend BI
Derivative
Show Graphs
Intensity
UV spectrum & components
UV Spectrum
Baseline
Nitrate Component
Br- Component
Residuals - Abs x 20
Absorbance
Wavelength (nm)
200
300
Start Wavelen.
217
End Wavelen.
240
Fix Salinity
Scan #
81
Date
11/08/2003
Time
11:57:05
Ref
1080.46
Temp
14
Fit Error
.00046
Salinity PSS
28.94
Nitrate uM
3.48
HS- uM
0
Intercept
.31961
Slope1
-.0013382
Slope2

Extensive sensor validation effort




10
12
14
16
SST (°C)
M1
M2
37.1°N
36.7°N
36.3°N
35.9°N
122.9°W
122.5°W
122.1°W
121.7°W

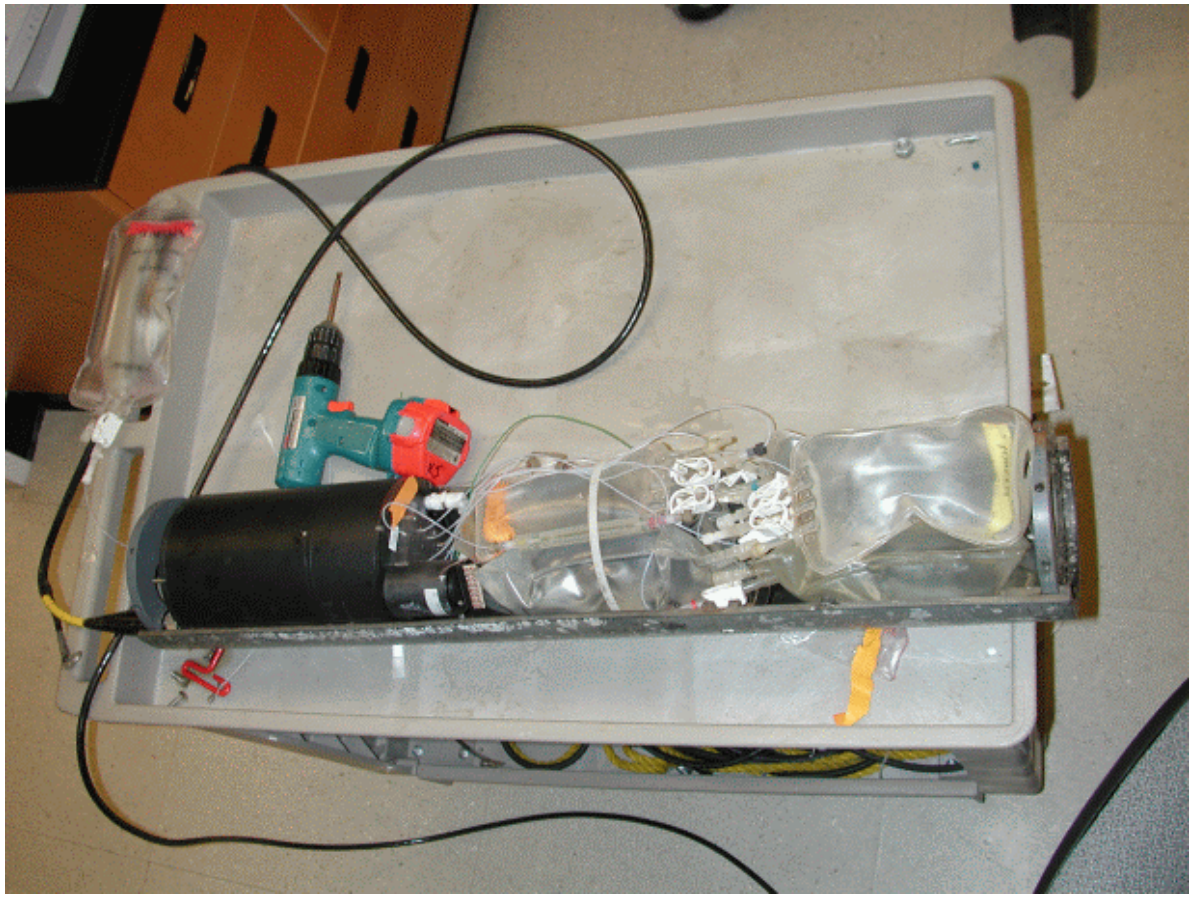

0.2
0.4
1
2
4
8
Chlorophyll (mg m^{-3})
37.1°N
36.7°N
36.3°N
35.9°N
122.9°W
122.5°W
122.1°W
121.7°W


Wind (knots)
20
10
0
-10
-20
Temperature (°C)
18
16
14
12
10
Nitrate (μM)
25
20
15
10
5
0
Chlorophyll (μg/L)
15
10
5
0
7/1/03
10/1/03
1/1/04
4/1/04

M B A R I

DigiSCAN (**Digi**tal **S**ubmersible **C**hemical **AN**alzyer)

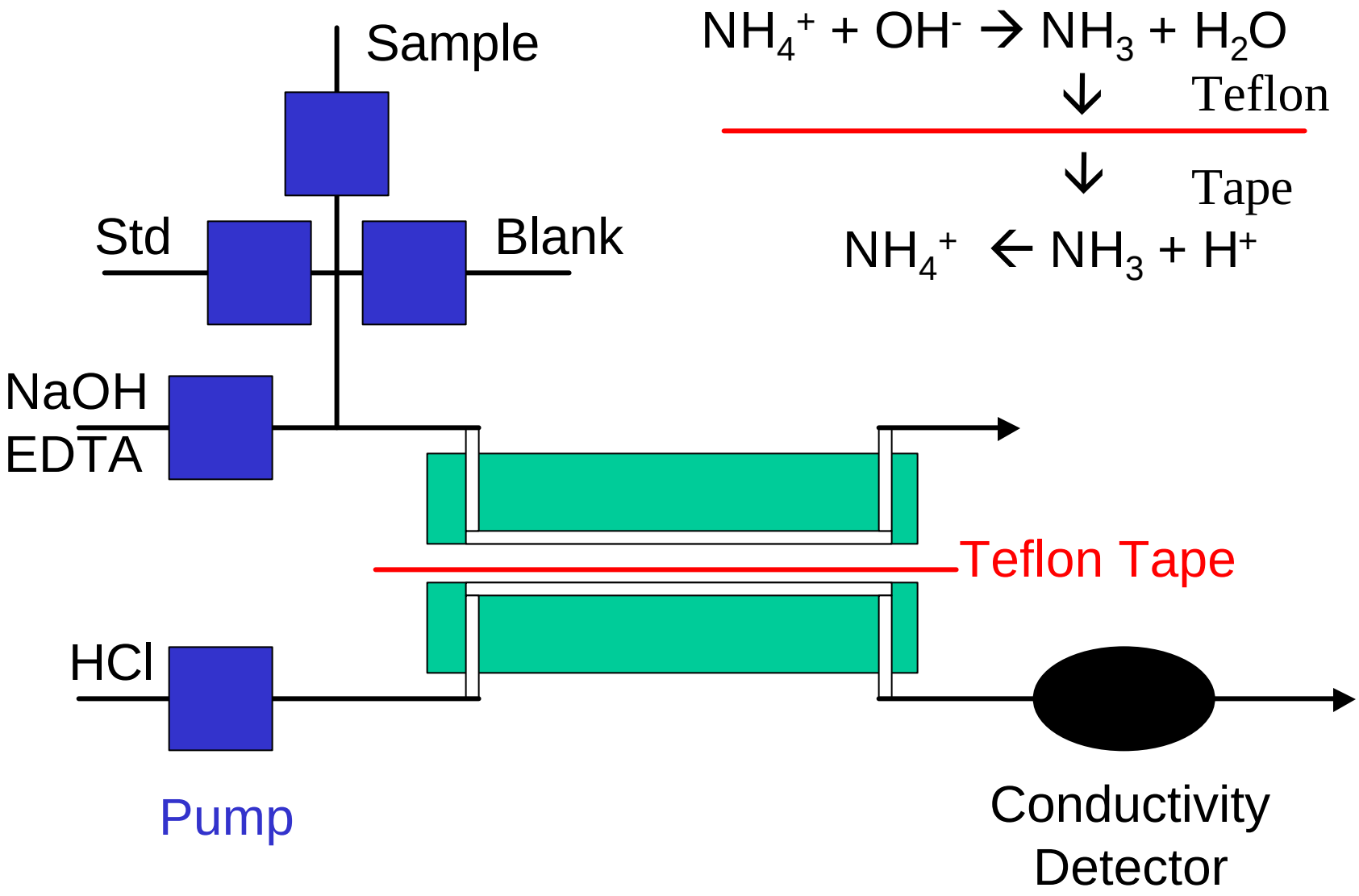
- commercially available as YSI 9600 Nutrient Monitor
- Allows for wet chemistry techniques to be used *in situ.*
- NO_3^-, NH_4^+, HPO_4^{2-}, $Si(OH)_4$, TCO_2, Cu^{2+}, Zn^{2+}

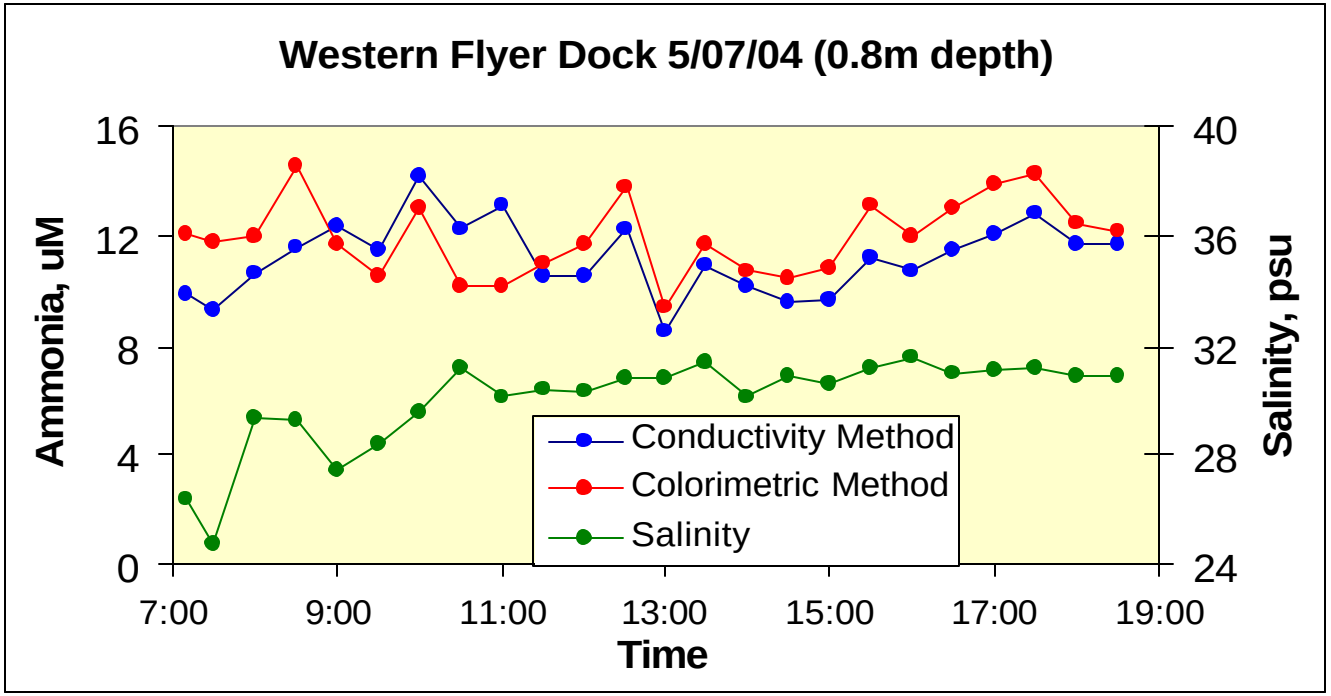


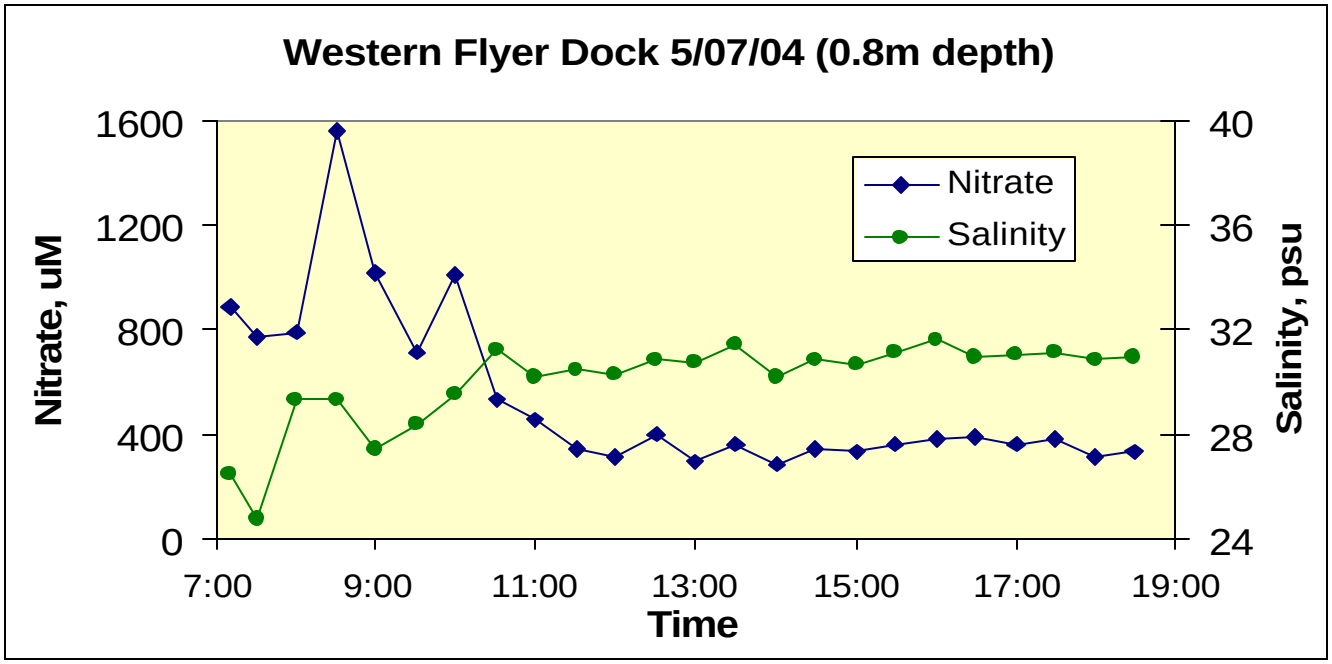
A hybrid of Continuous Flow Analysis, Flow Injection Analysis and a little Sequential Injection Analysis

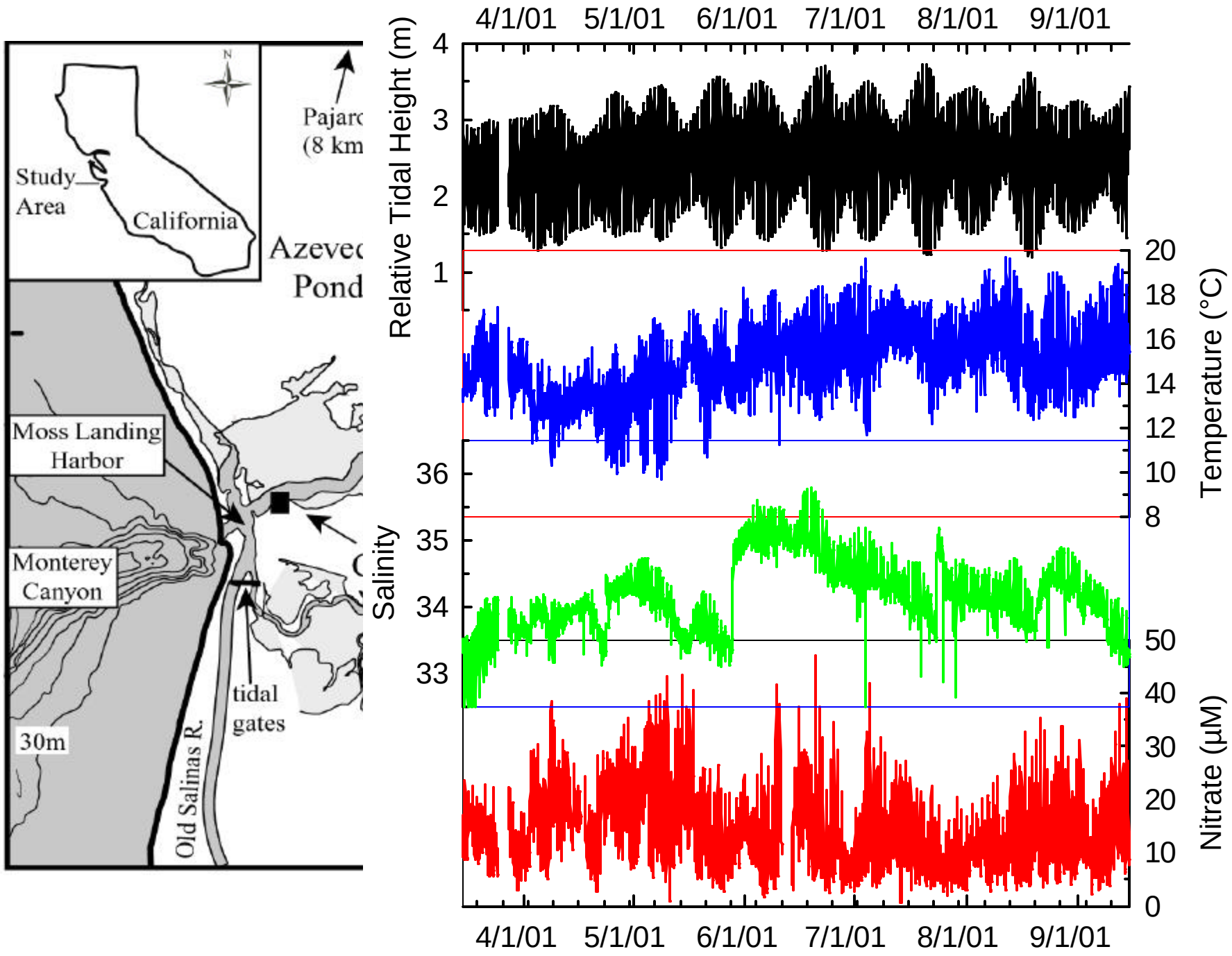
Robust in environments with biofouling and adaptable to many chemistries

Ammonia DigiSCAN

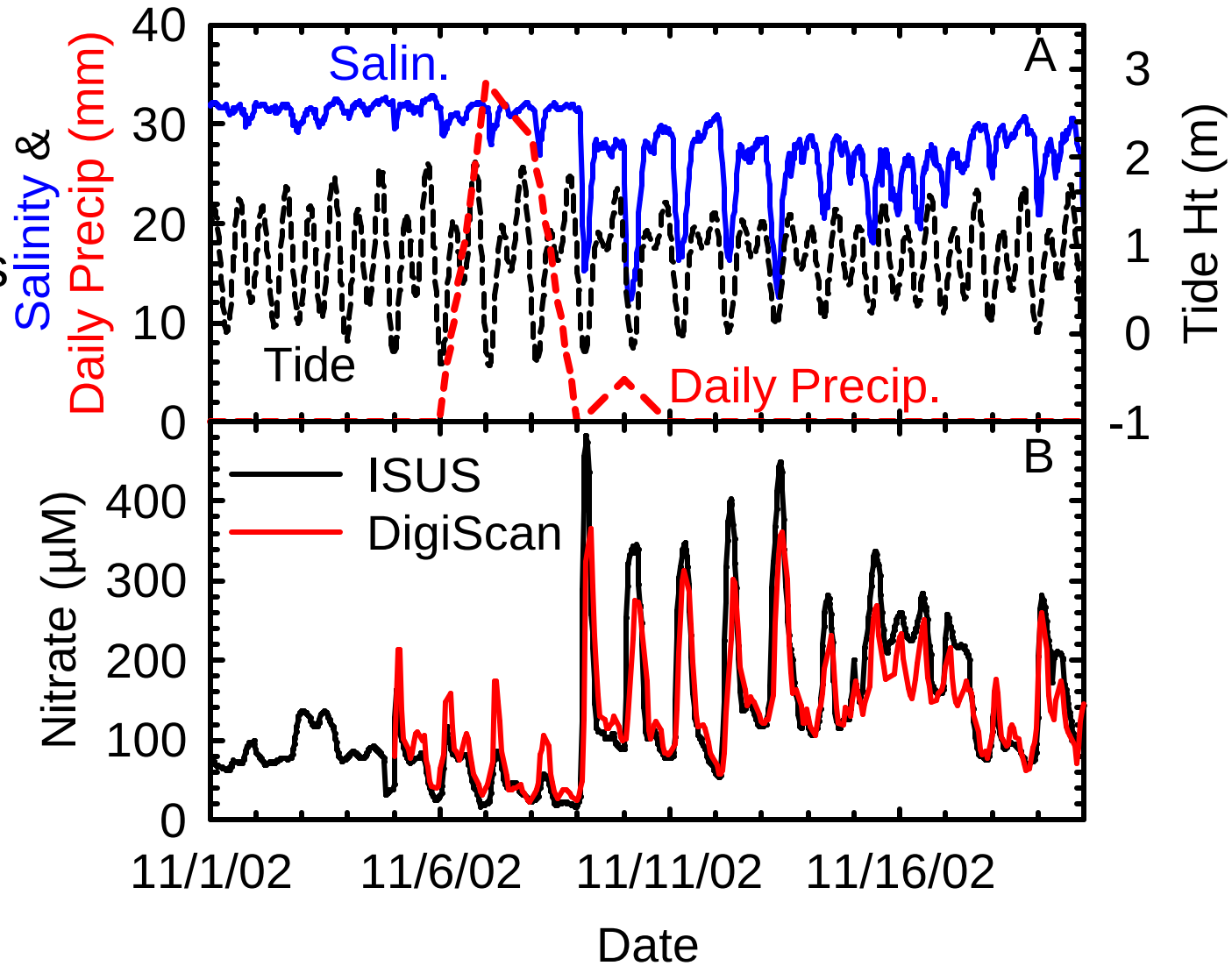



Western Flyer Dock 5/07/04 (0.8m depth)
Ammonia, uM
Salinity, psu
Time
Conductivity Method
Colorimetric Method
Salinity
16
12
8
4
0
40
36
32
28
24
7:00
9:00
11:00
13:00
15:00
17:00
19:00

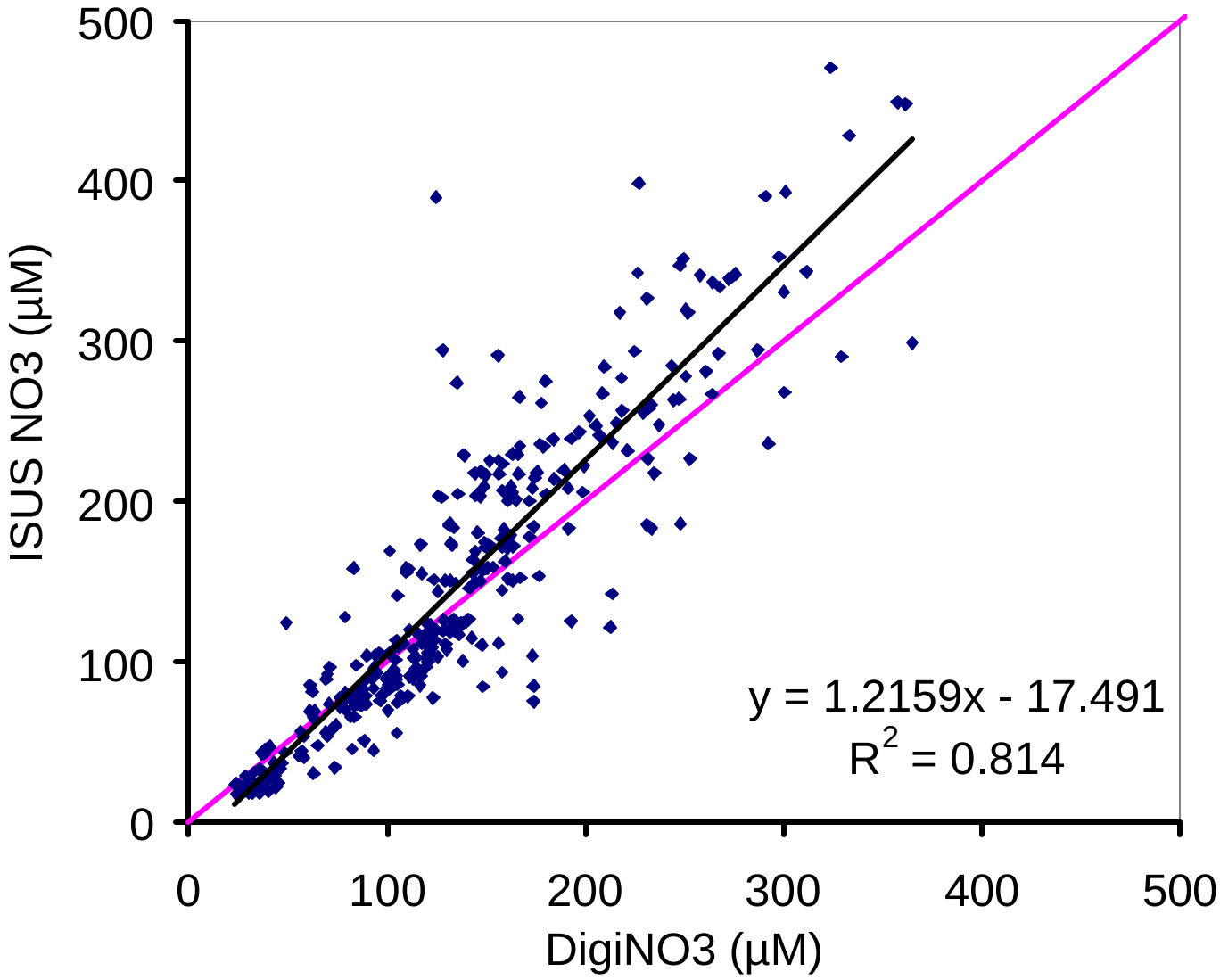

Western Flyer Dock 5/07/04 (0.8m depth)
Nitrate, uM
Salinity, psu
Time
Nitrate
Salinity
1600
1200
800
400
0
40
36
32
28
24
7:00
9:00
11:00
13:00
15:00
17:00
19:00


Study Area
California
Pajaro
(8 km
Azevedo
Pond
Moss Landing Harbor
Monterey Canyon
tidal gates
30m
Old Salinas R.
4/1/01
5/1/01
6/1/01
7/1/01
8/1/01
9/1/01
Relative Tidal Height (m)
Salinity
Temperature (°C)
Nitrate (µM)

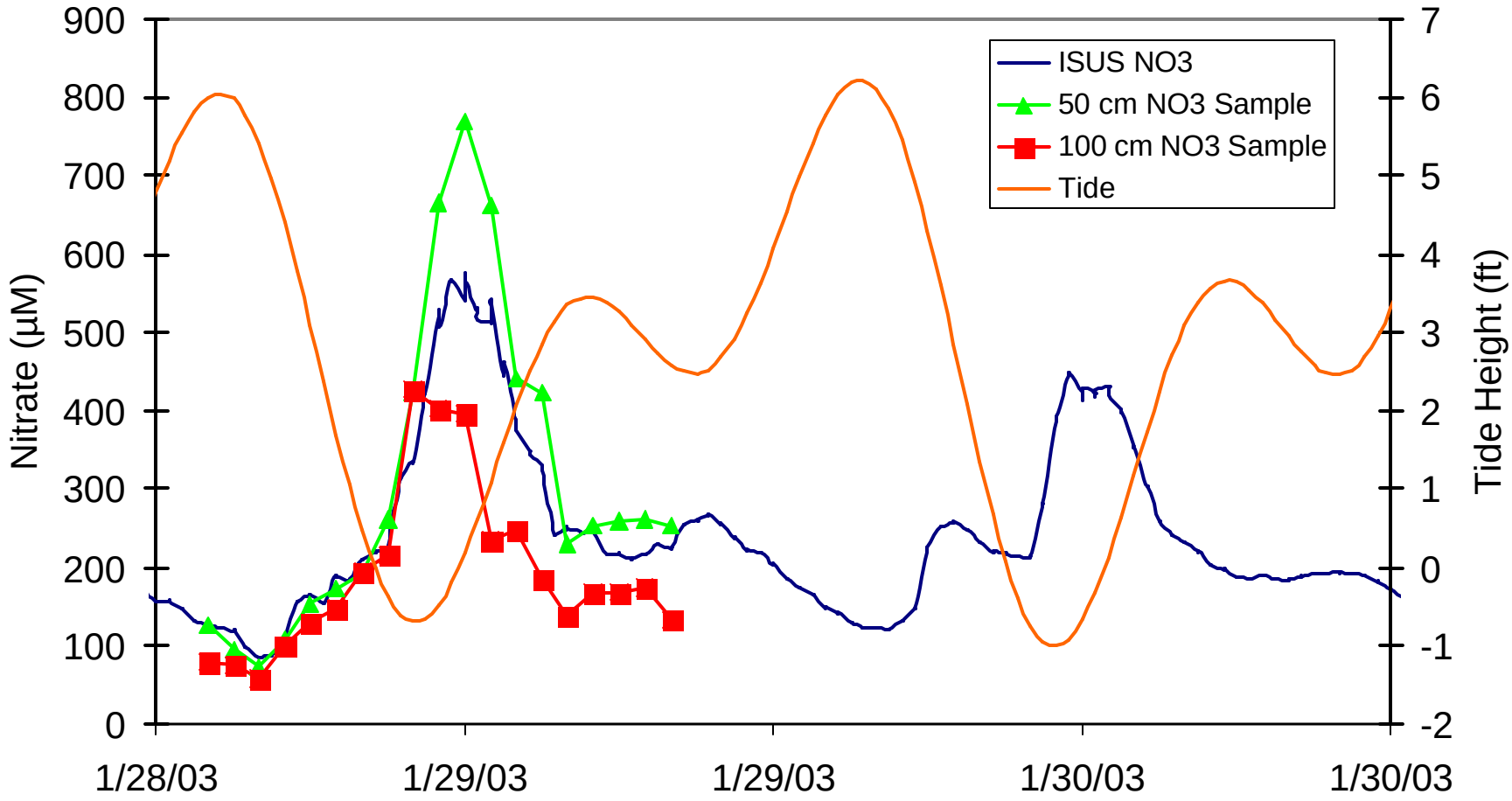
Comparison of ISUS and DigiSCAN nitrate measurements at LML.



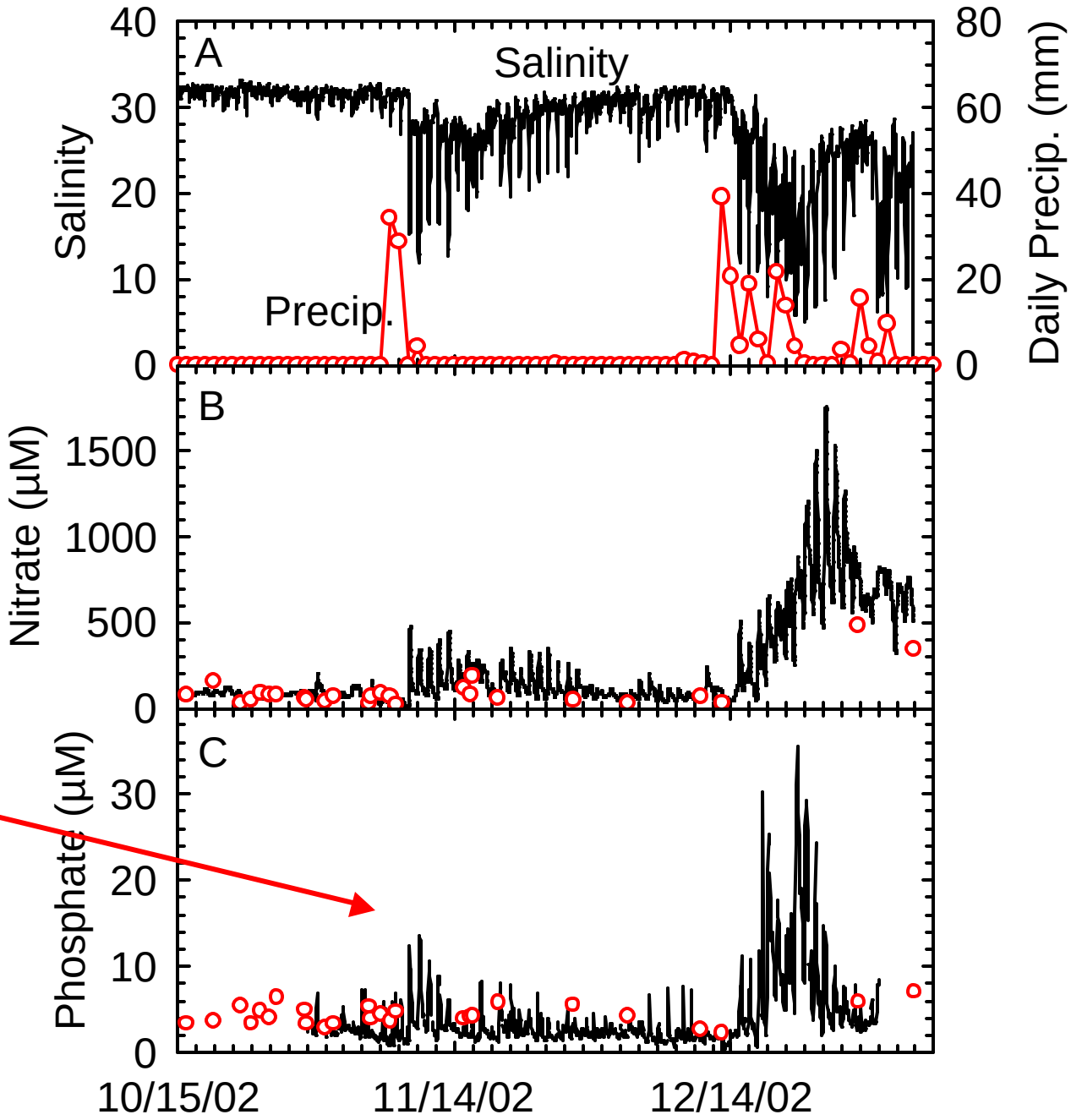
ISUS Comparison with DigiScan Wet Chemical Analyzer in Moss Landing Harbor. Deviations from Beer's law at high nitrate with 1 cm pathlength in DigiScan.



Spatial variability makes comparisons difficult

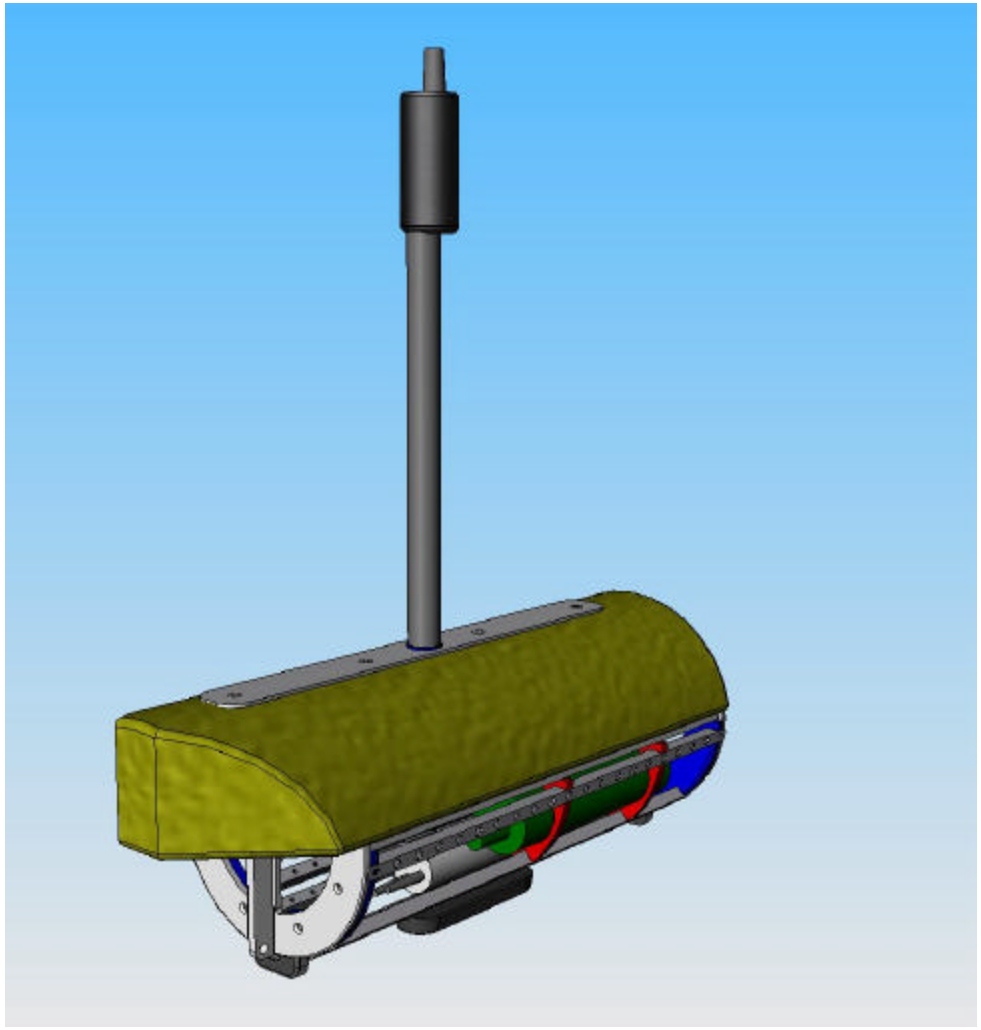


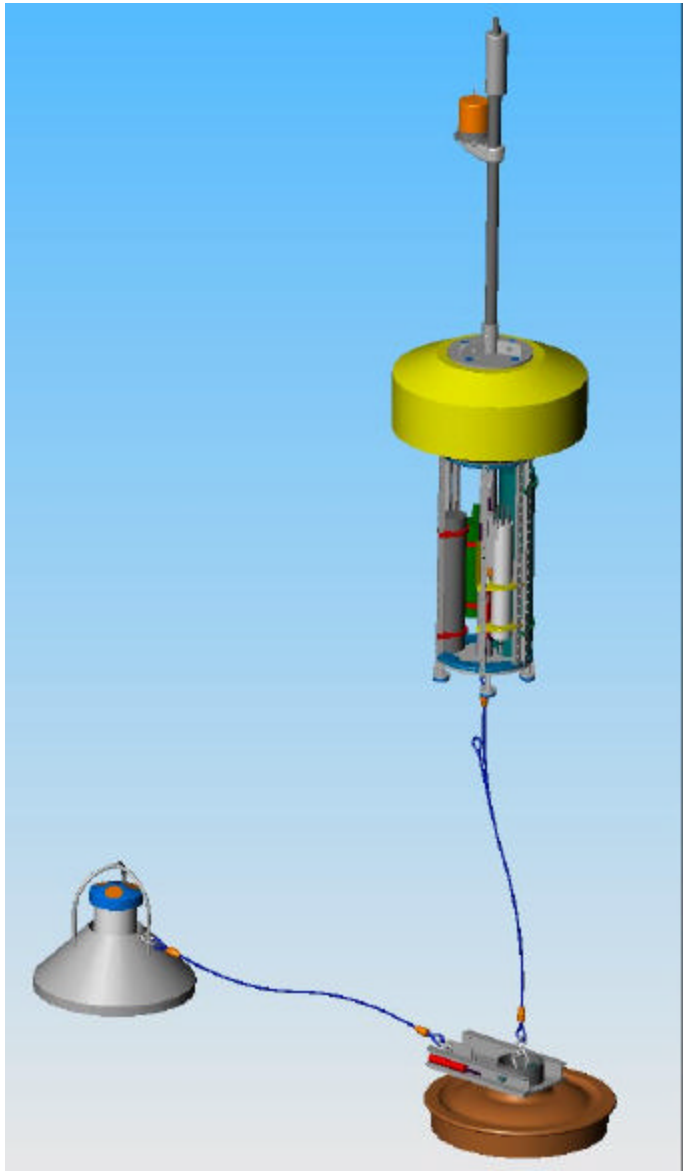
Phosphate


A
Salinity
Precip.
Salinity
Daily Precip. (mm)
40
30
20
10
0
80
60
40
20
0
B
Nitrate (µM)
1500
1000
500
0
C
Phosphate (µM)
30
20
10
0
10/15/02
11/14/02
12/14/02

LOBO Mooring Design

Shallow and ‘deep’ water moorings designed at MBARI

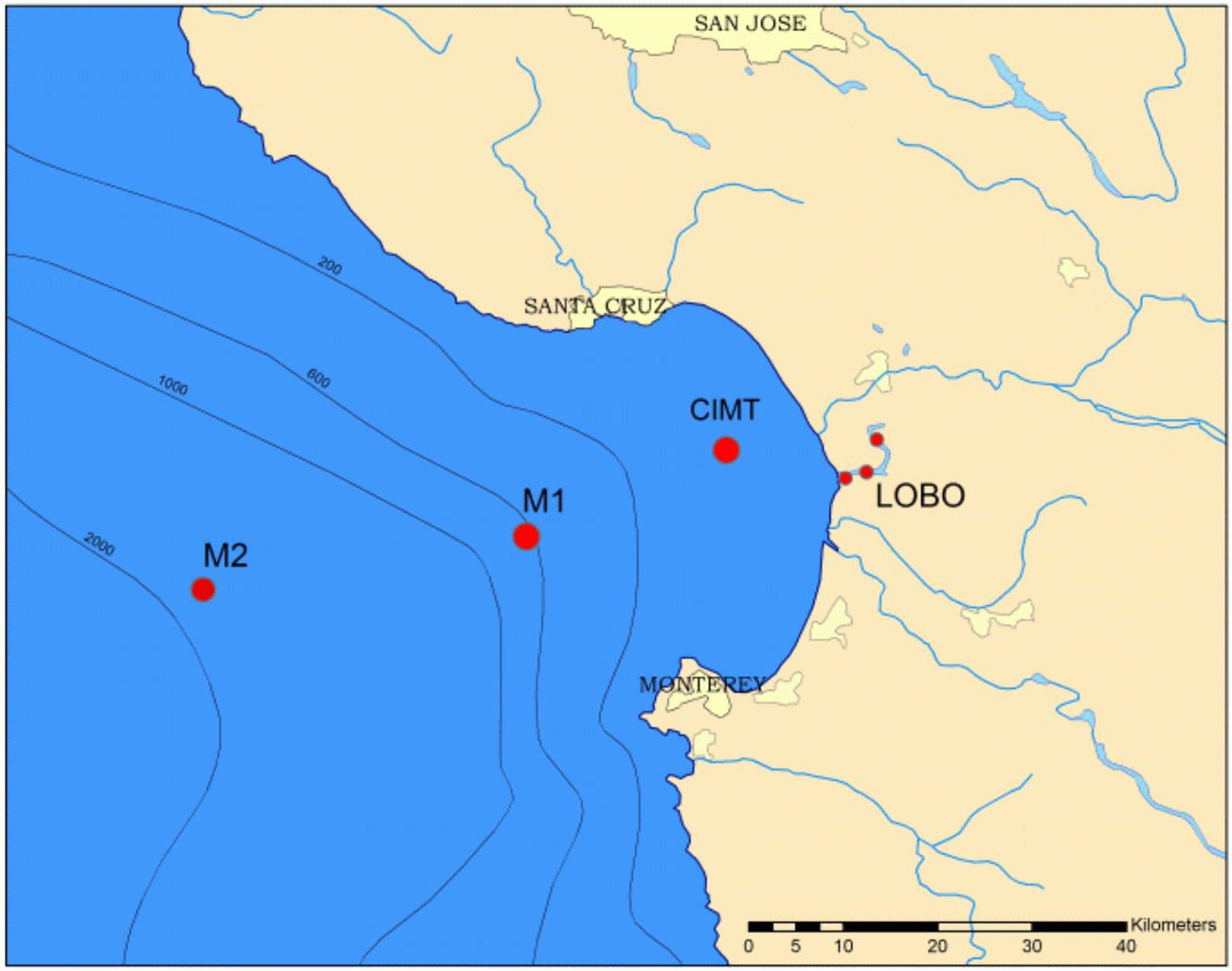




Illustrations courtesy of Hans Jannasch

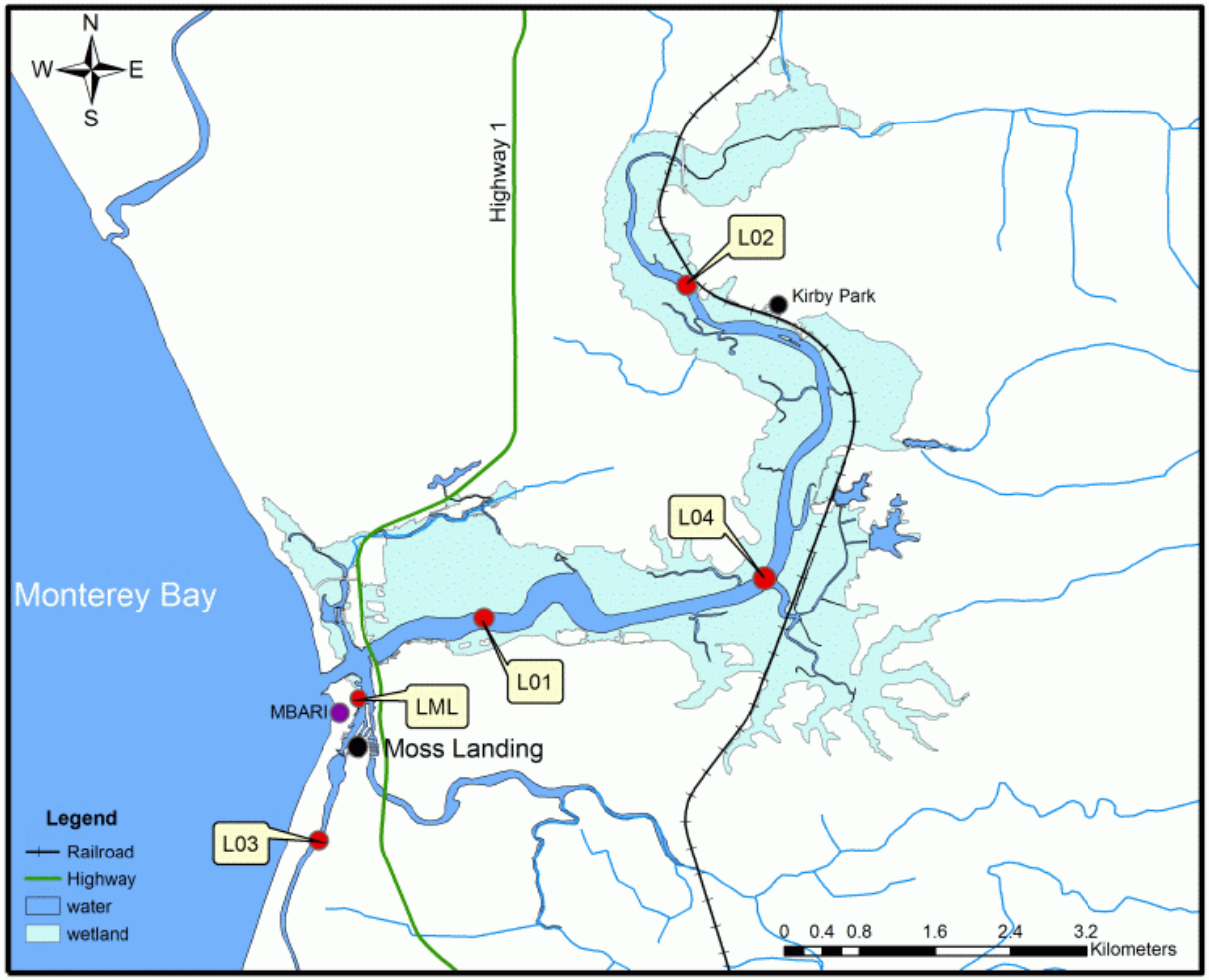

CF 8911 XS
SHEILA B.

MBARI Mooring Network

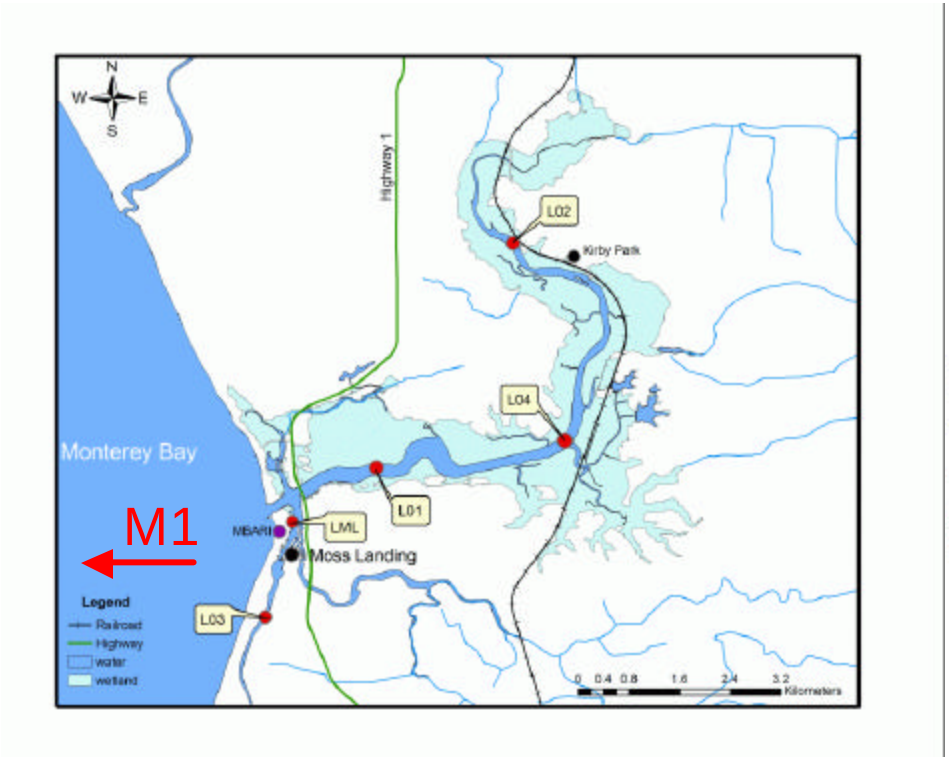


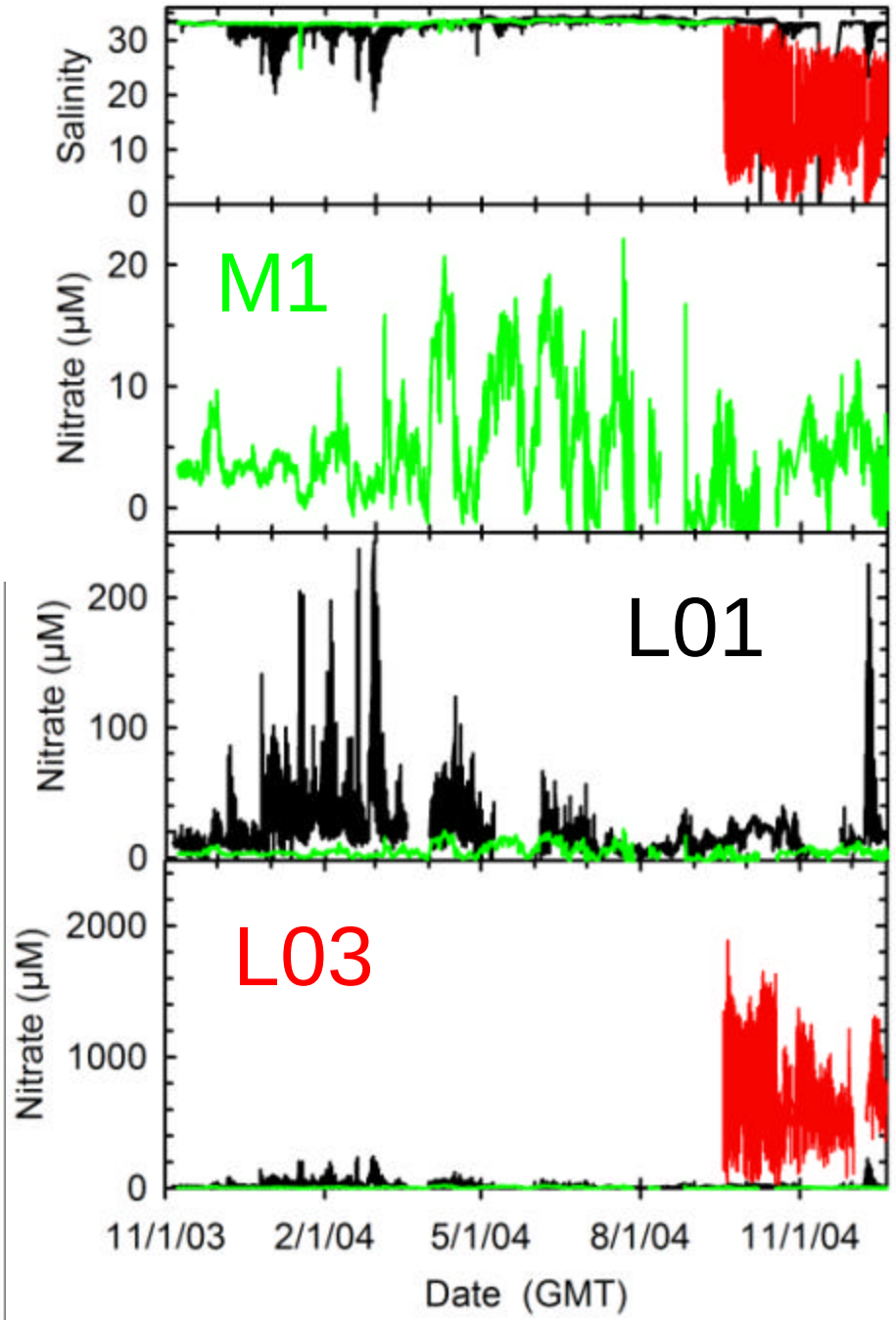
LOBO Mooring Network

- Nutrient sources
  - Carneros Creek
  - Parsons Slough
  - Moro-Cojo Slough
  - Old Salinas River
  - Monterey Bay
  - Non-point source groundwater
- Nutrient sinks
  - Phytoplankton
  - Sea grass
  - Marshes
  - Sediments
  - Monterey Bay

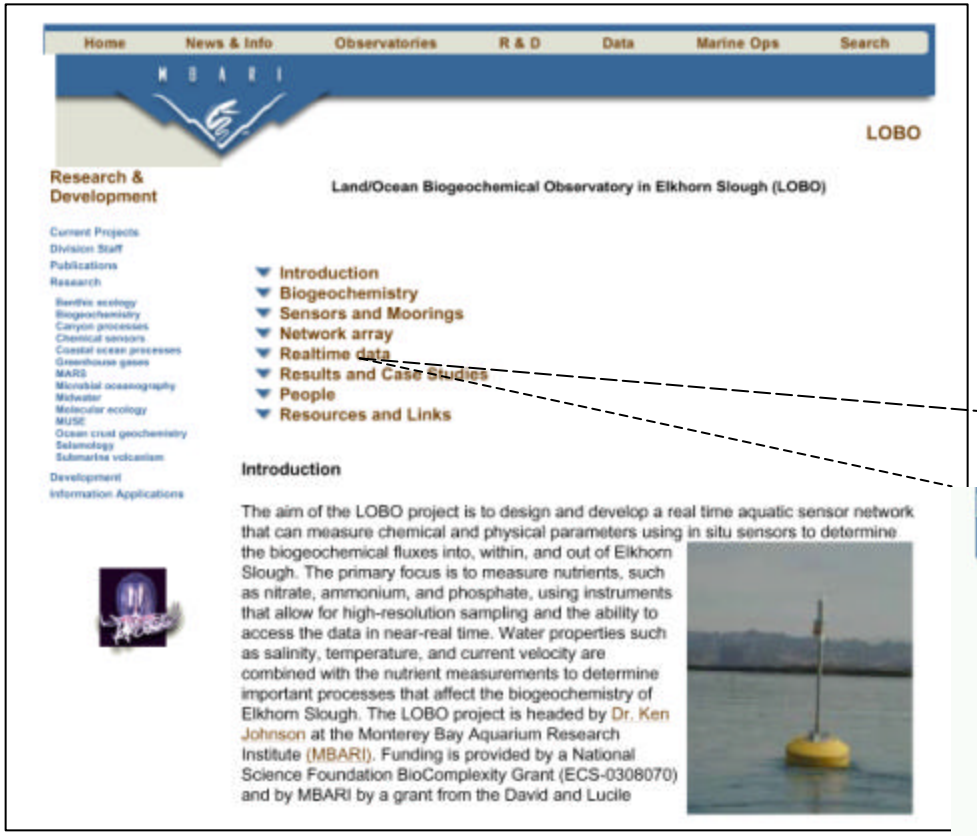


Comparison of Nitrate concentrations in Monterey Bay (M1), Main channel of Elkhorn Slough (L01), and Old Salinas river channel (L03) in 2004.

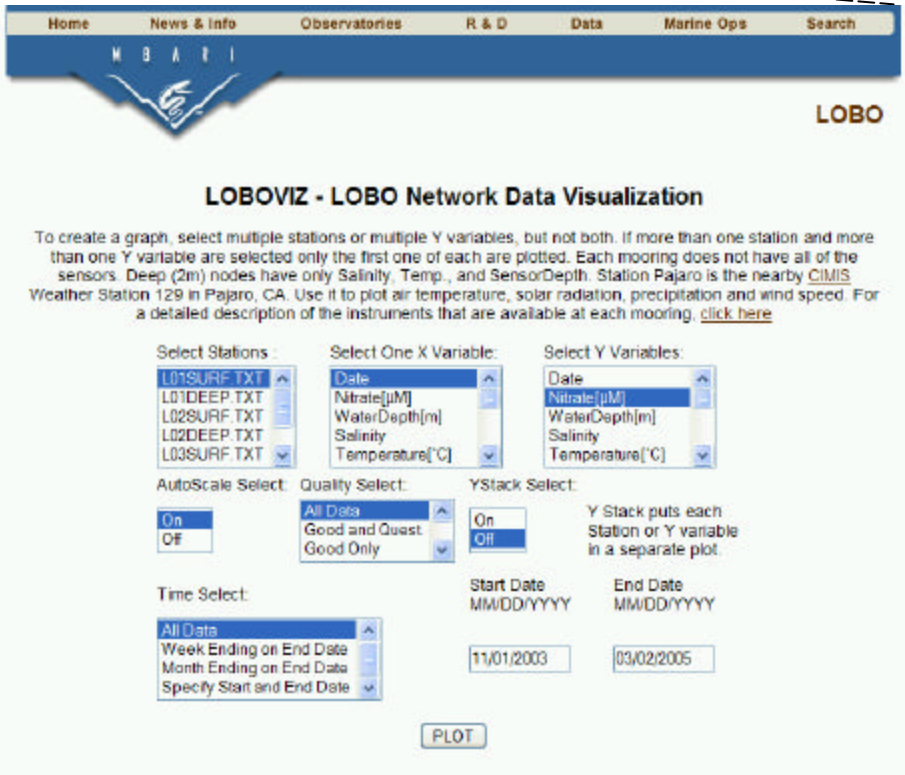




LOBO on the WEB - www.mbari.org/lobo



Our web page provides background information, details of the instrumentation and the mooring network, and some summary articles



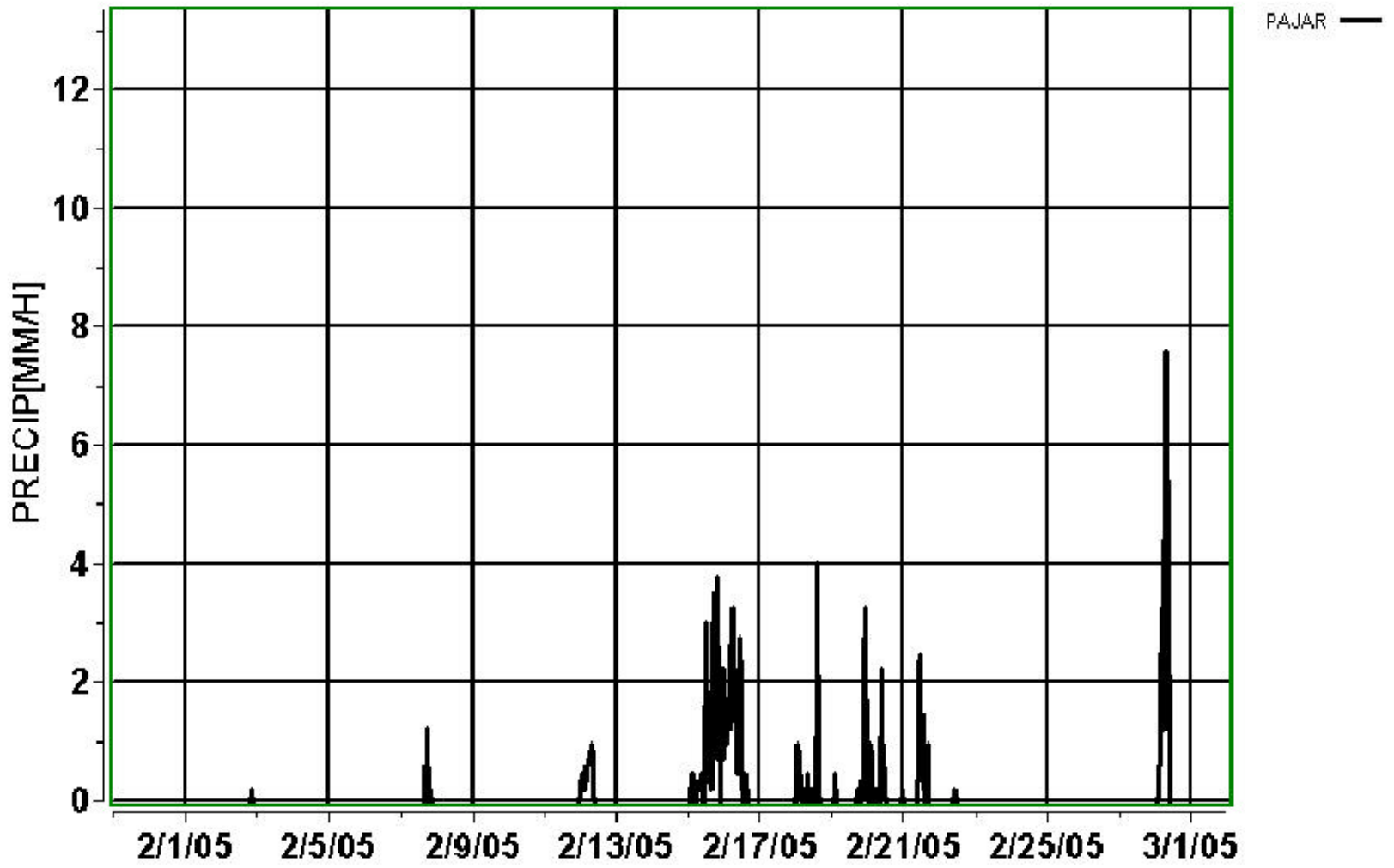
Data is accessed through **LOBOViz** – an online program for data visualization. Can we do “on-line” biogeochemistry?

'LOBOVIZ Plot Page' - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

AltaVista - Welcome | Charles Thiel's Links to... | Chem Sensors M1 ISU... | Chem Sensors M2 ISU... | CORE - Consortium for ...

LOBOVIZ Plot Page Station(s) PAJARO.TXT Variable(s) Precip[mm/h]



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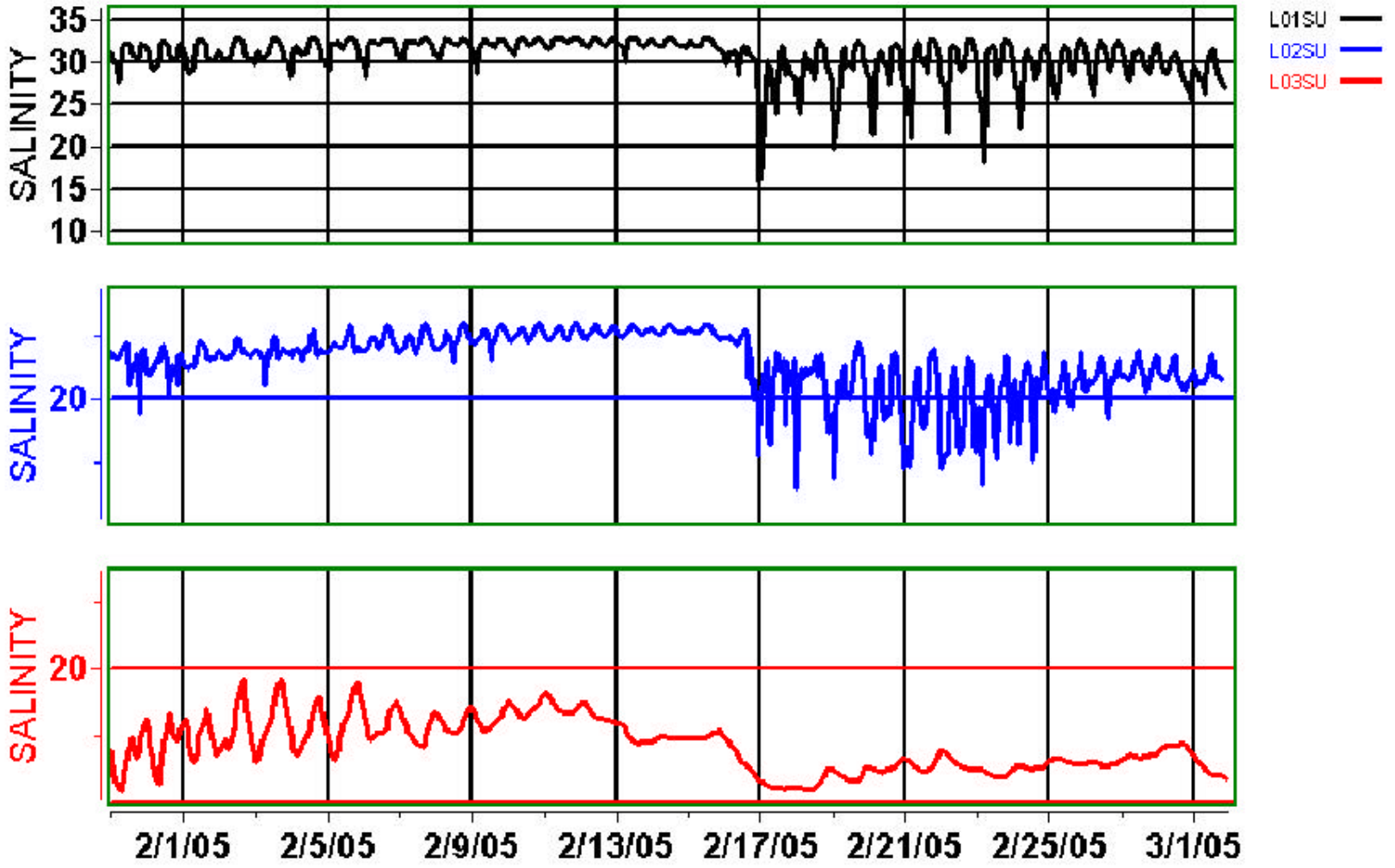
LOBOVIZ Plot Page Station(s) L01SURF.TXT;L02SURF.TXT;L03SURF.TXT Variable(s) Salinity



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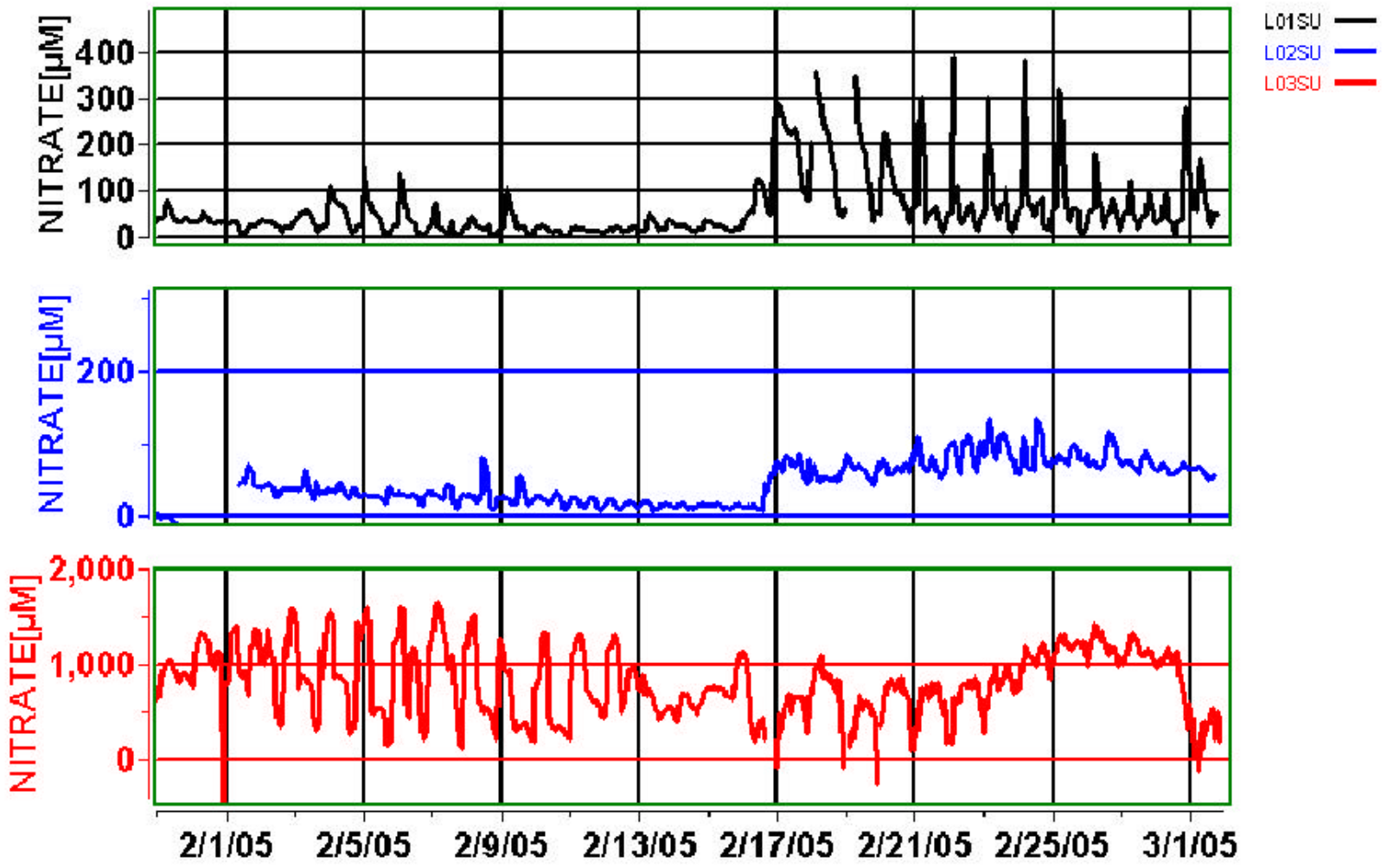
LOBOVIZ Plot Page Station(s) L01SURF.TXT;L02SURF.TXT;L03SURF.TXT Variable(s) Nitrate[µM]



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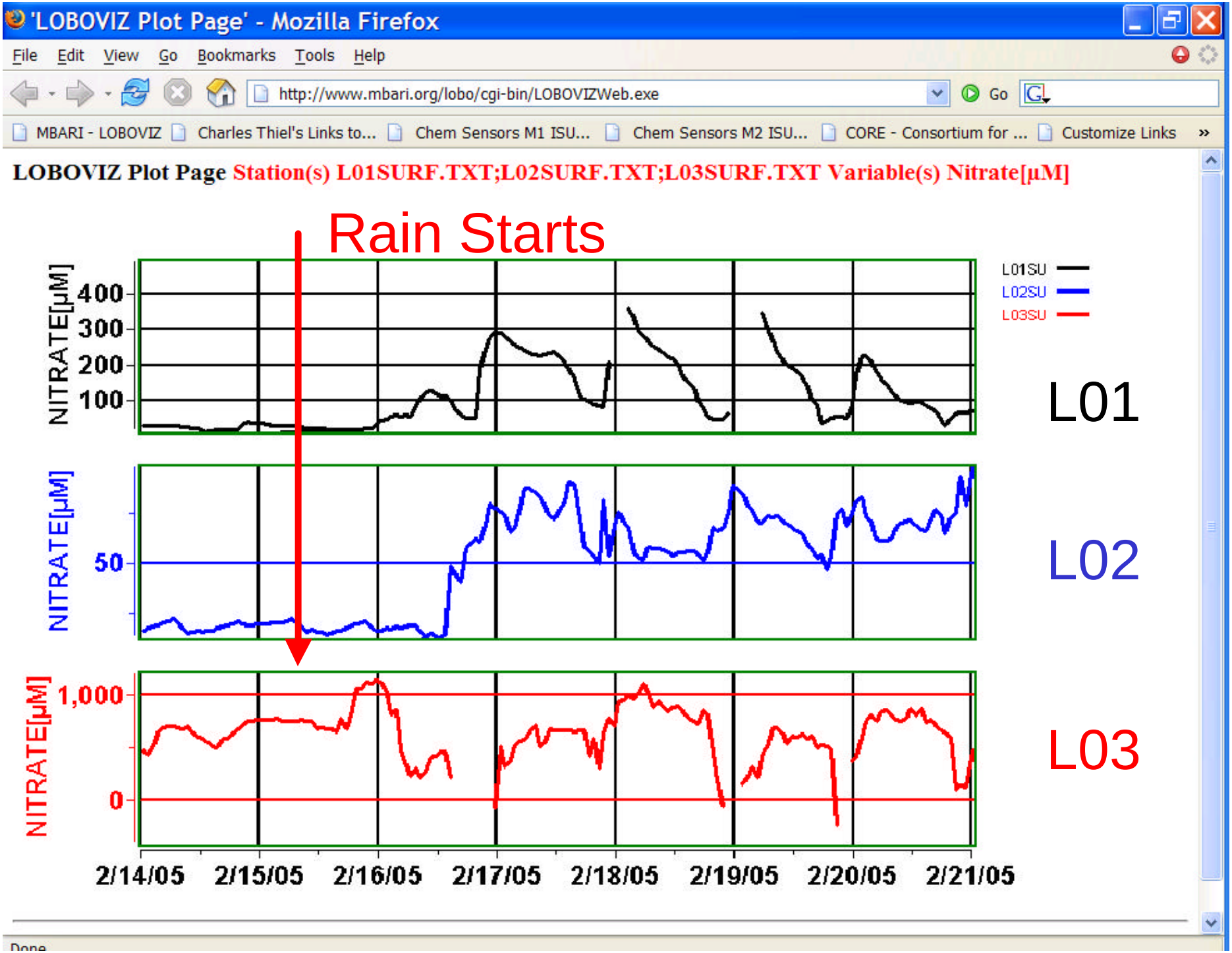
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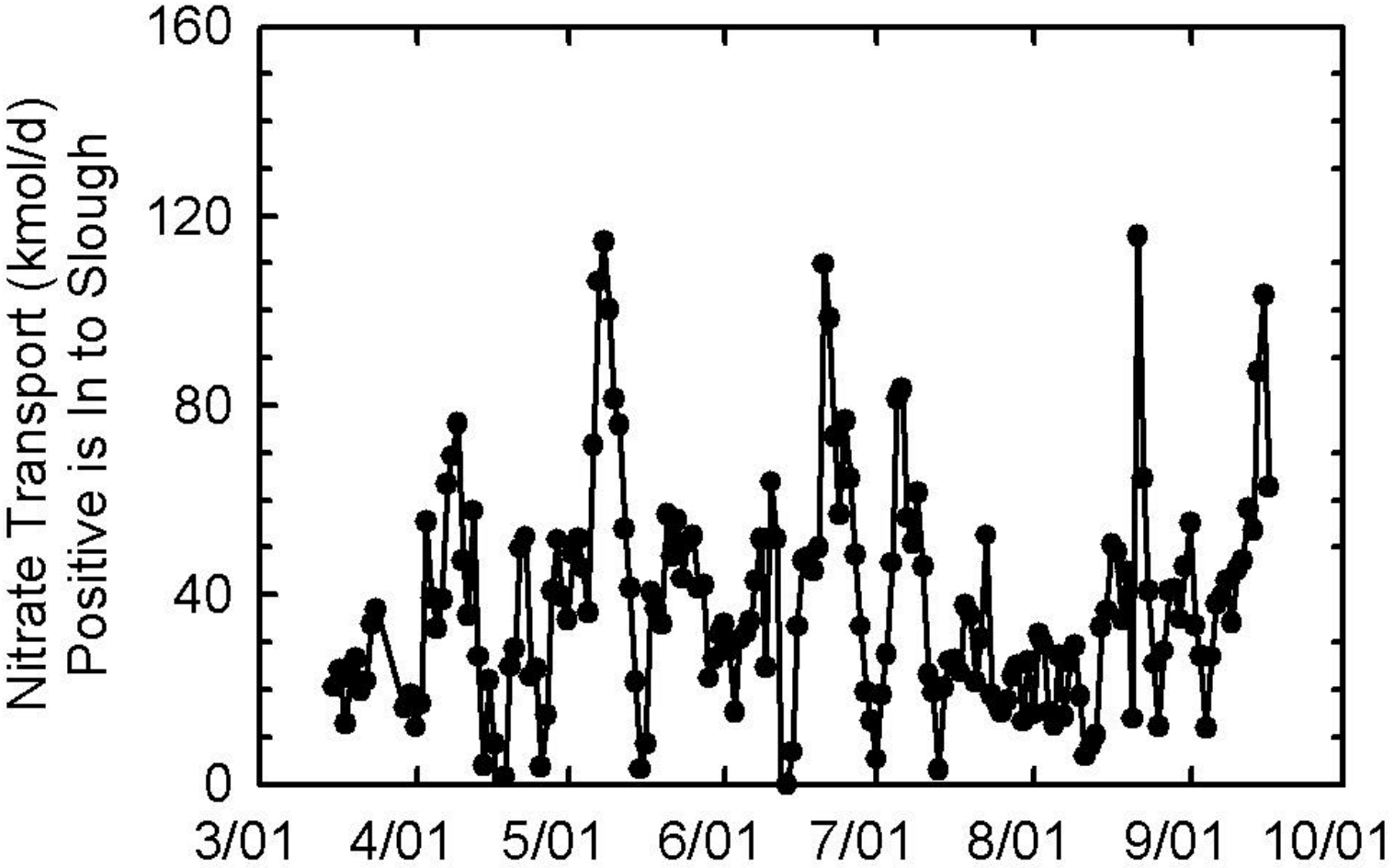
http://www.mbari.org/lobo/cgi-bin/LOBOVIZWeb.exe
Go
MBARI - LOBOVIZ
Charles Thiel's Links to...
Chem Sensors M1 ISU...
Chem Sensors M2 ISU...
CORE - Consortium for ...
Customize Links
LOBOVIZ Plot Page Station(s) L01SURF.TXT;L02SURF.TXT;L03SURF.TXT Variable(s) Nitrate[µM]
Rain Starts
NITRATE[µM]
400
300
200
100
L01SU
L02SU
L03SU
L01
NITRATE[µM]
50
L02
NITRATE[µM]
1,000
0
L03
2/14/05
2/15/05
2/16/05
2/17/05
2/18/05
2/19/05
2/20/05
2/21/05
Done

Daily nitrate transport past L01 – Slough imports an average of 40 kmol NO_3/d. A nitrate sink, not a source! (Chapin et al., Estuaries, Oct. 2004)



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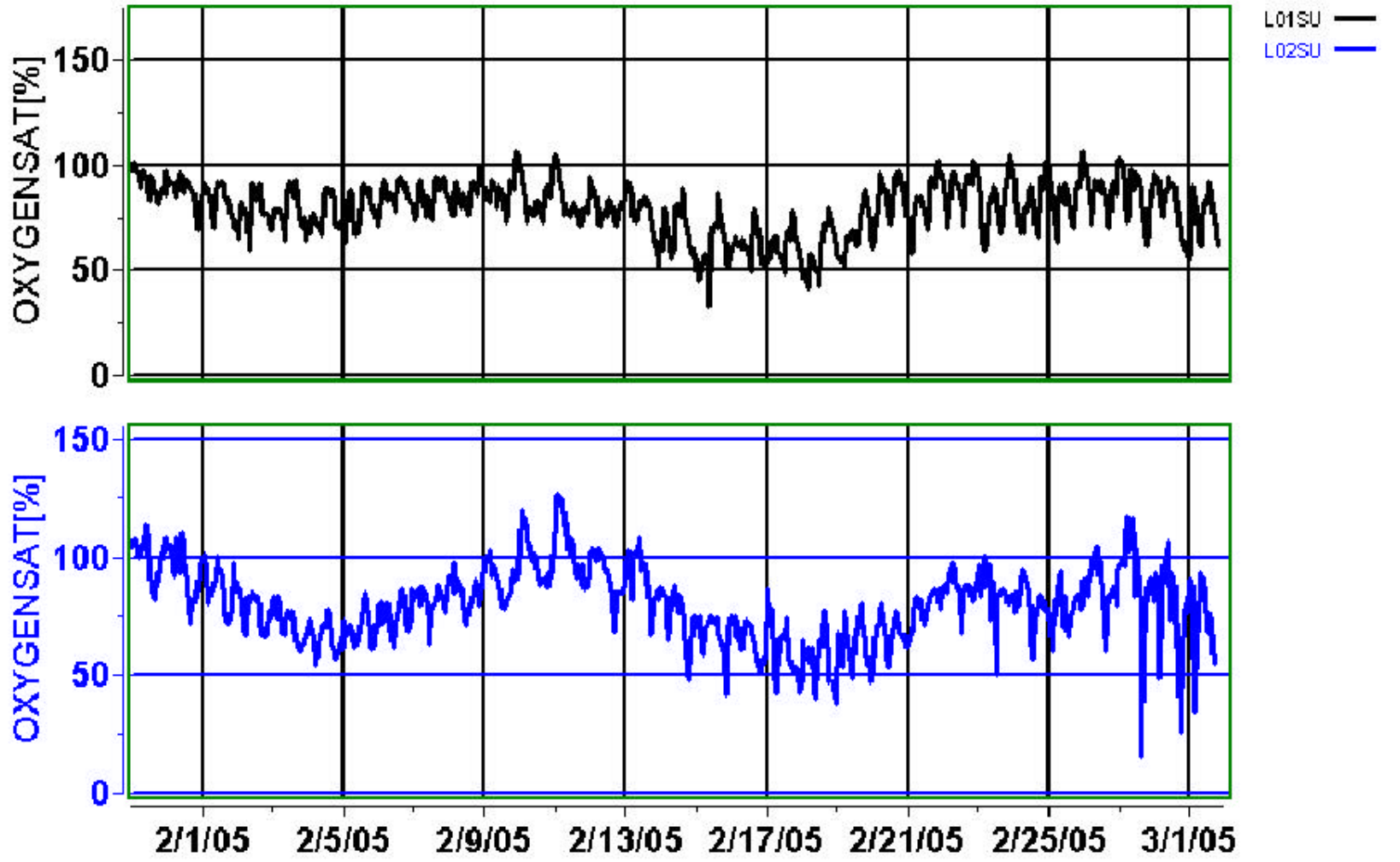
AltaVista - Welcome | Charles Thiel's Links to... | Chem Sensors M1 ISU... | Chem Sensors M2 ISU... | CORE - Consortium for ...

LOBOVIZ Plot Page Station(s) L01SURF.TXT;L02SURF.TXT Variable(s) OxygenSat[%]

Synchronous changes in other chemical parameters as storms pass through



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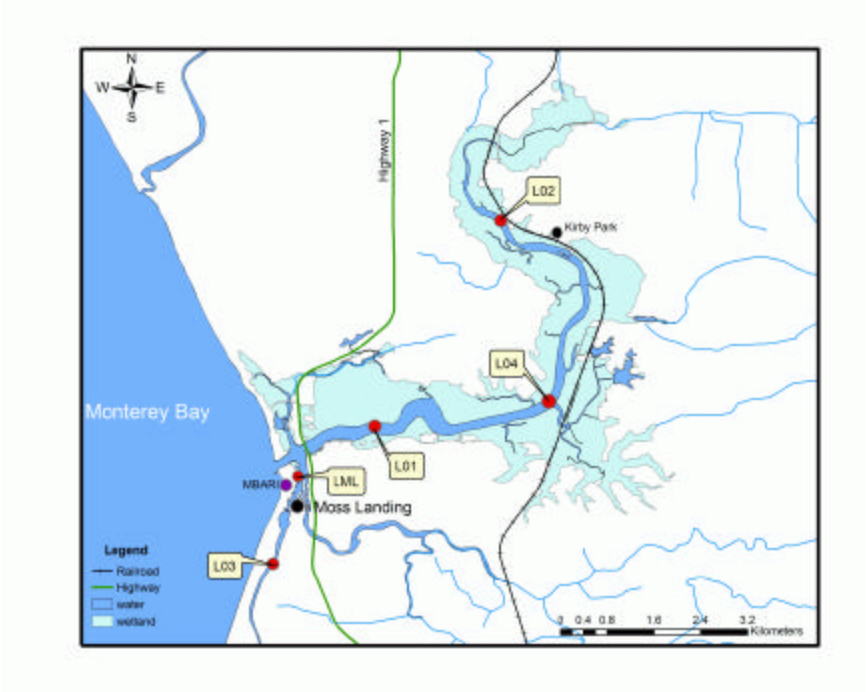
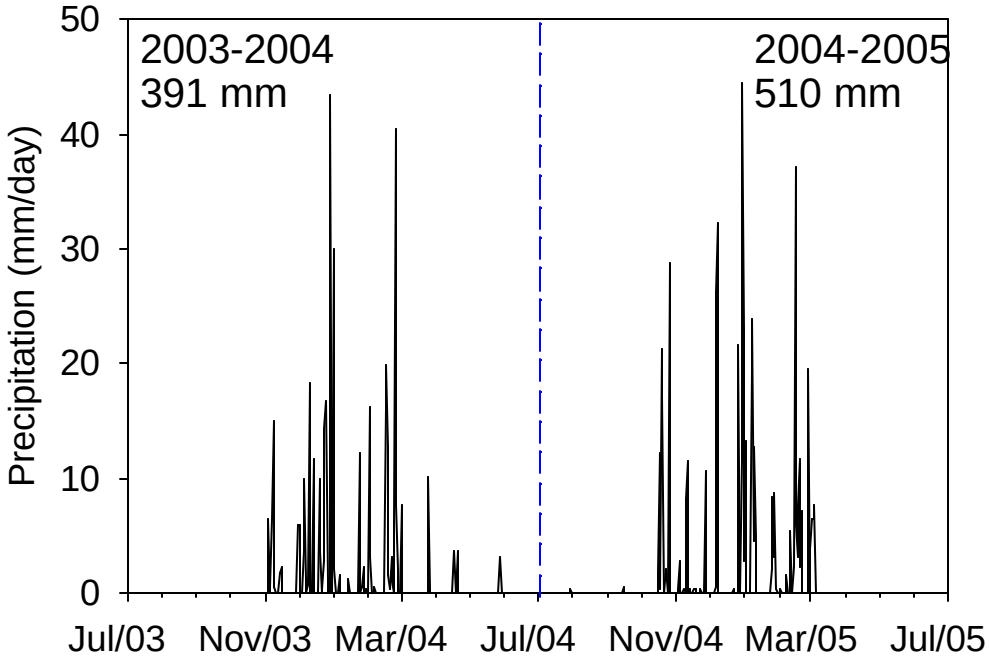
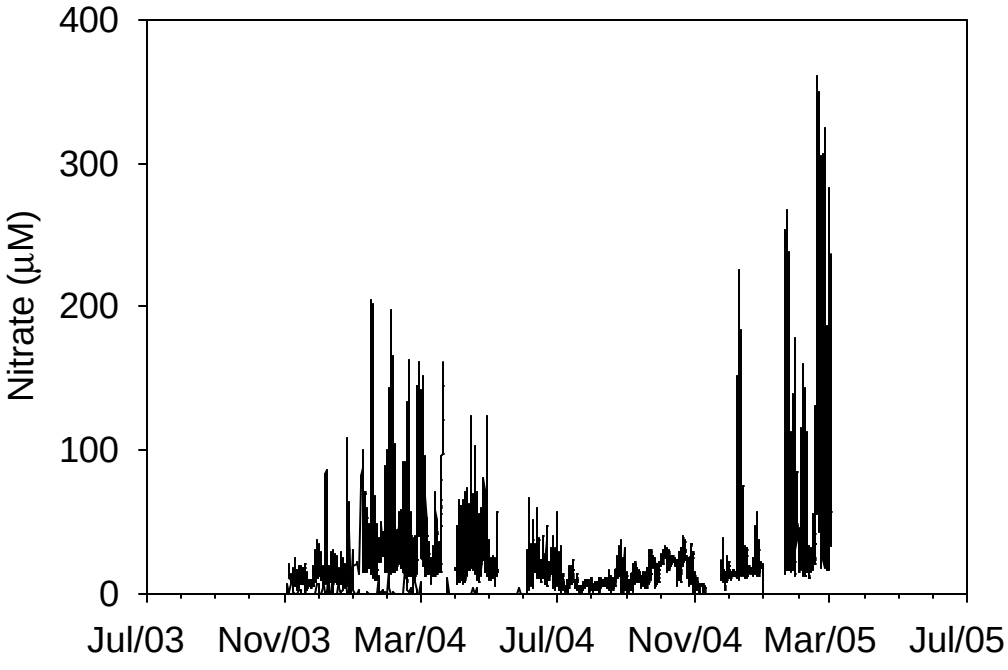
Seasonal Patterns

Highest Nitrate inputs to Elkhorn Slough during rainfall events. More nitrate in wetter years?

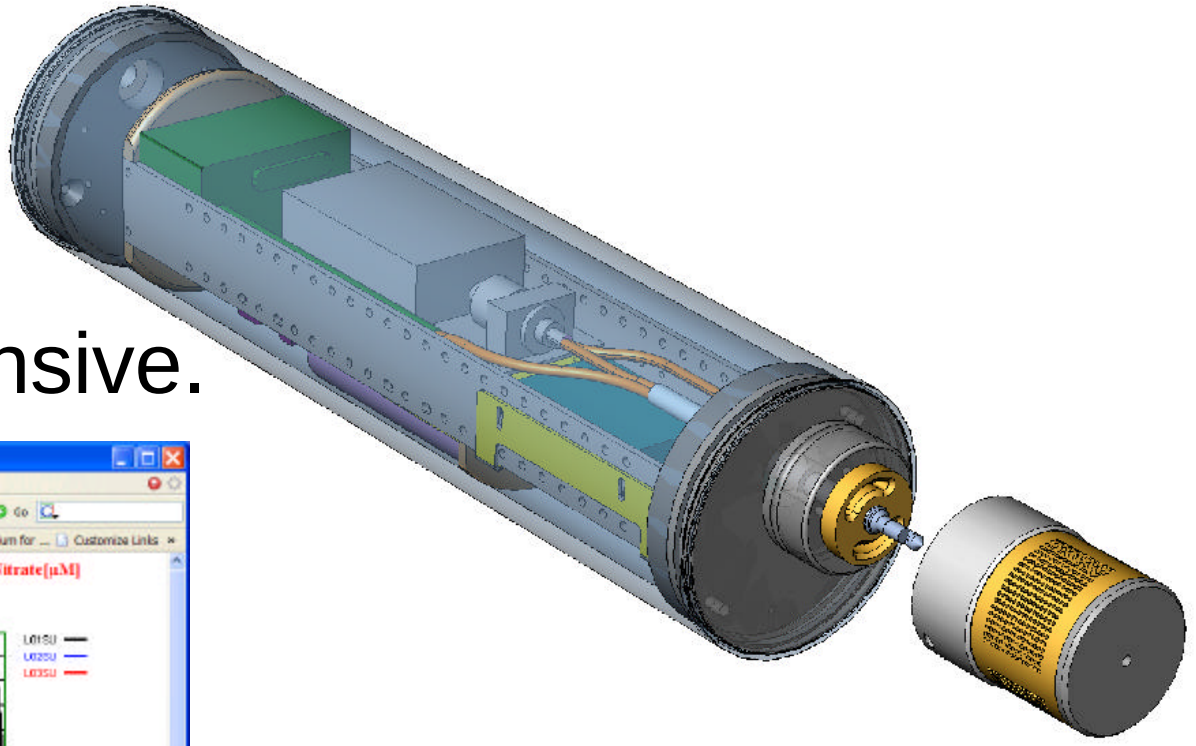


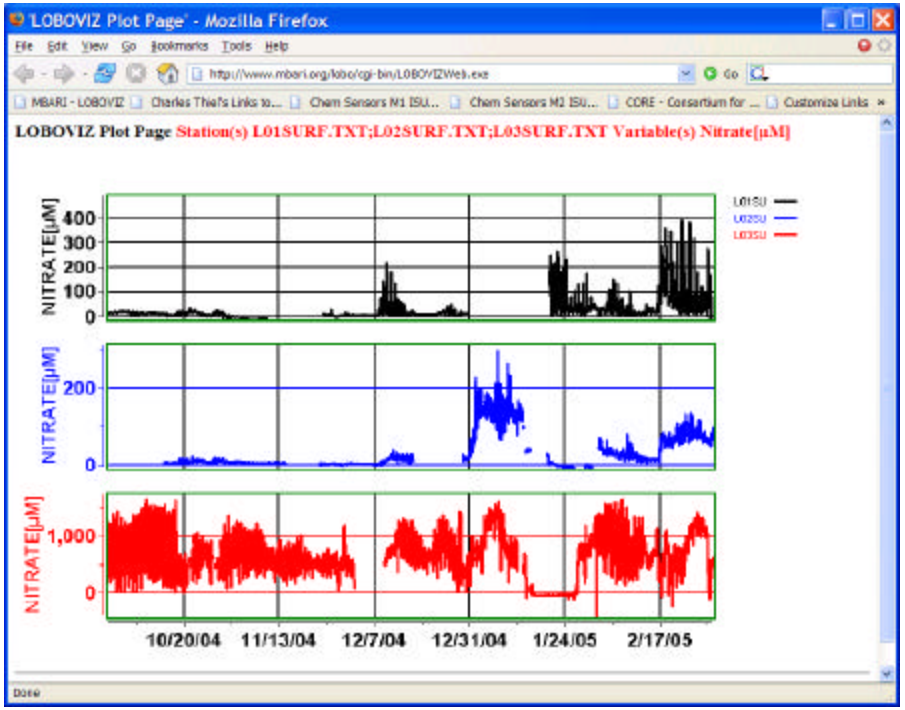




Sensors are working! We still need to make things more:

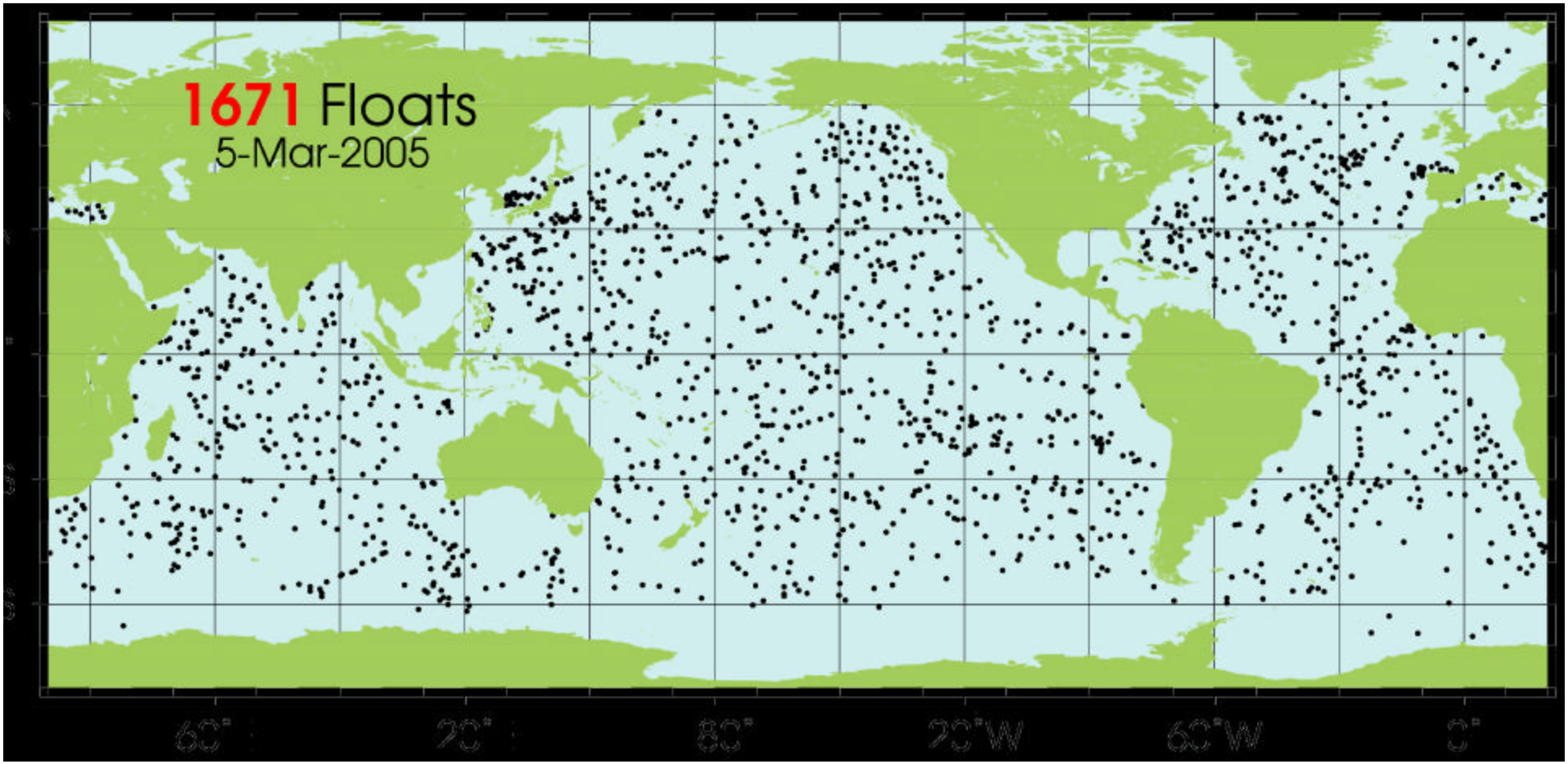
- robust
- accessible
- less labor intensive.





It's feasible to start thinking about the grand challenges:

The grand challenge for ocean biogeochemistry: Instrument the vertical profiling floats of the ARGO array (or an ARGO-like array) with chemical sensors to monitor global ocean productivity. USE THAT DATA TO PROVIDE THE CONTEXT FOR MORE FOCUSED PROCESS STUDIES.



The ARGO array is expected to grow to 3000 floats!

Acknowledgements

LOBO is funded by the NSF Biocomplexity in the Environment program, with additional support from the David and Lucile Packard Foundation.

IDEA: Instrumentation Development for Environmental Activities

M B A R I

www.mbari.org/lobo

Special thanks to:

John Douglas and the Moss Landing Marine Labs Small Boat Operations facility