SubChem Systems, Inc.

Cabled and Autonomous Submersible Chemical Analyzers for Coastal Observations

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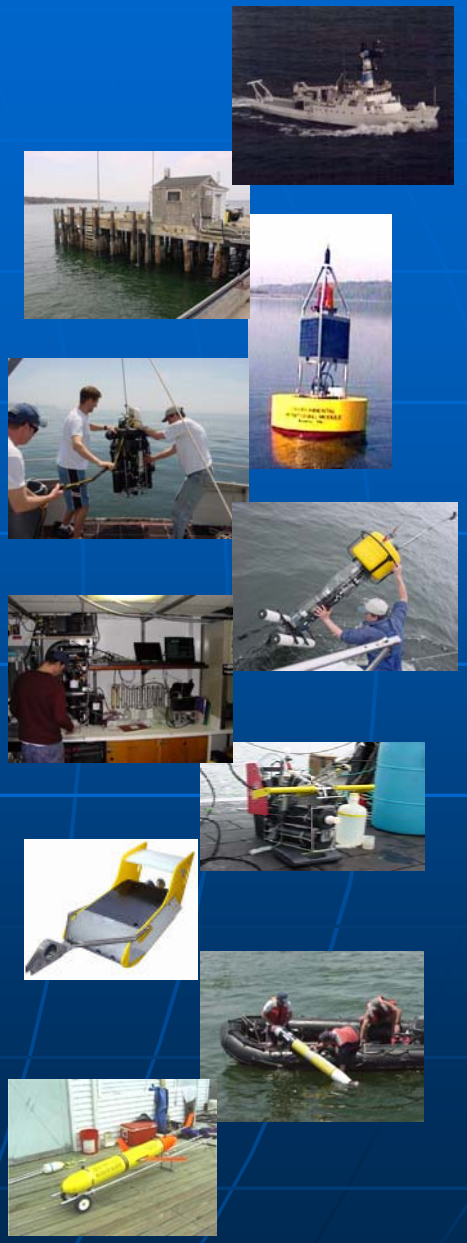
ABSTRACT

Submersible chemical analyzers are being developed for deployment on multiple types of ocean observation platforms. The compact Autonomous Profiling Nutrient Analyzer (APNA) was designed to provide high-resolution vertical profiles of multiple nutrients in real-time while deployed as a payload for an autonomous moored profiling system. The APNA was also adapted for deployment on the REMUS autonomous underwater vehicle. The APNA is comprised of a multi-channel reagent delivery and optical detection module and a reservoir for reagents and standards. A variety of chemicals can be determined with this instrumentation using continuous-flow optical detection methodologies that have been optimized for rapid *in situ* measurements. Field tests with APNA prototypes have demonstrated its capability to autonomously profile nutrient concentrations in real-time and provide the *in situ* self-calibration data needed to verify *in situ* performance. The APNA is being utilized to elucidate the role of nutrient gradients in thin plankton layer dynamics in coastal waters.

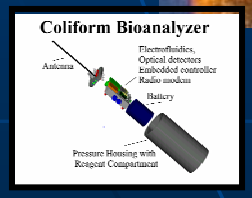
Coastal Sampling Platforms for Chemical Analyzers

- **Fixed depth - Cabled or Autonomous**
  - Boat, dock, pier or moored buoy (i.e. YSI)
- **Vertical Profiles**
  - Ship-deployed vertical profiler (CTD)
  - Autonomous moored vertical profiler (IOPC)
- **Horizontal Profiles**
  - Underway ship-board sampling system
- **Horizontal and Vertical Profiles**
  - Ship-deployed towed undulating vehicle
    - Acrobat (URI, WET Labs, SubChem)
    - Nu-Shuttle (NMFS)
  - Autonomous underwater vehicle (AUV)
    - Propeller (i.e. REMUS – URI, UMASS, NUWC)
    - Glider (i.e. Slocum glider – WHOI, Rutgers)
    - Drifters/Floats



New Submersible Analyzer Technologies

1. SubChemPak Profiling Analyzer
2. Autonomous Profiling Nutrient Analyzer
3. SubChem Analyzer Payload for REMUS
4. WET Labs Cycle – Moored Nutrient Analyzer
5. SubBio Analyzer – Bacterial Indicators



4- Channel Submersible Chemical Analyzer

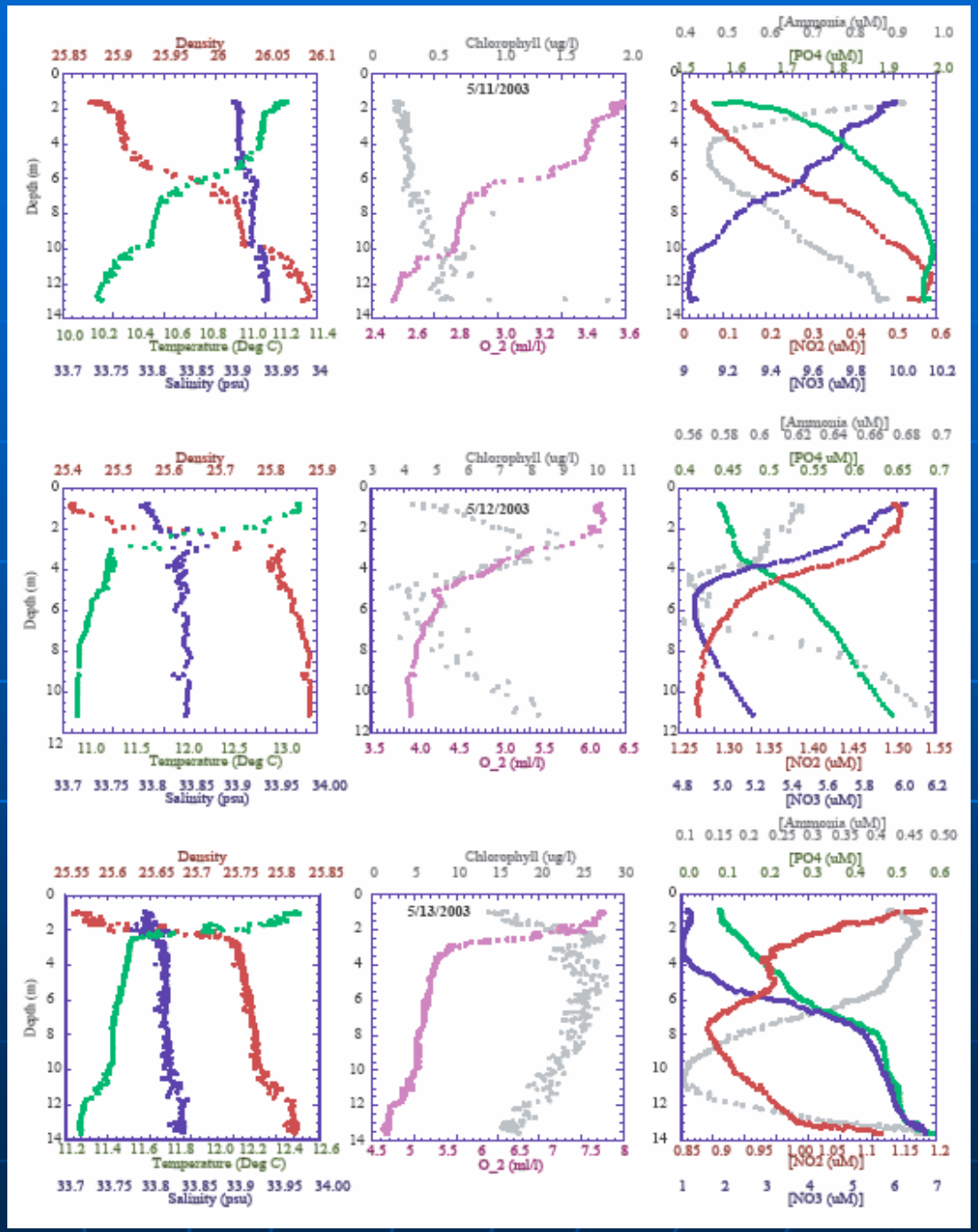
- Real time results
- Fast response
- High resolution profiles
- Multi-chemical capability
- Trace concentrations
- *In situ* calibration
- Accurate determinations

Santa Barbara

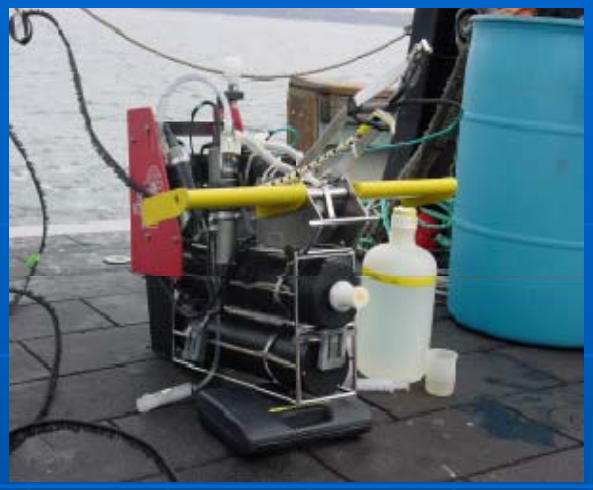
Vertical Profiler

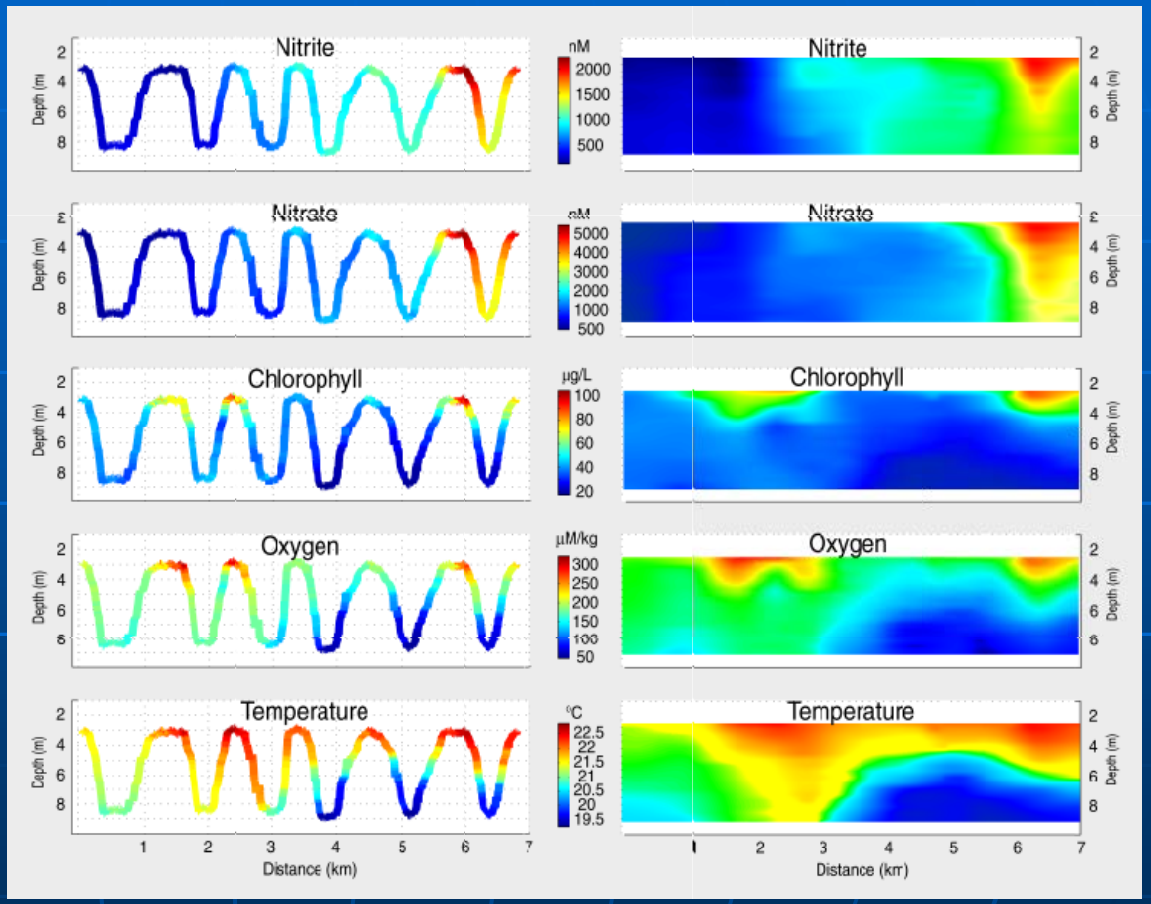
2-Day Nutrient Time Series

May 2003



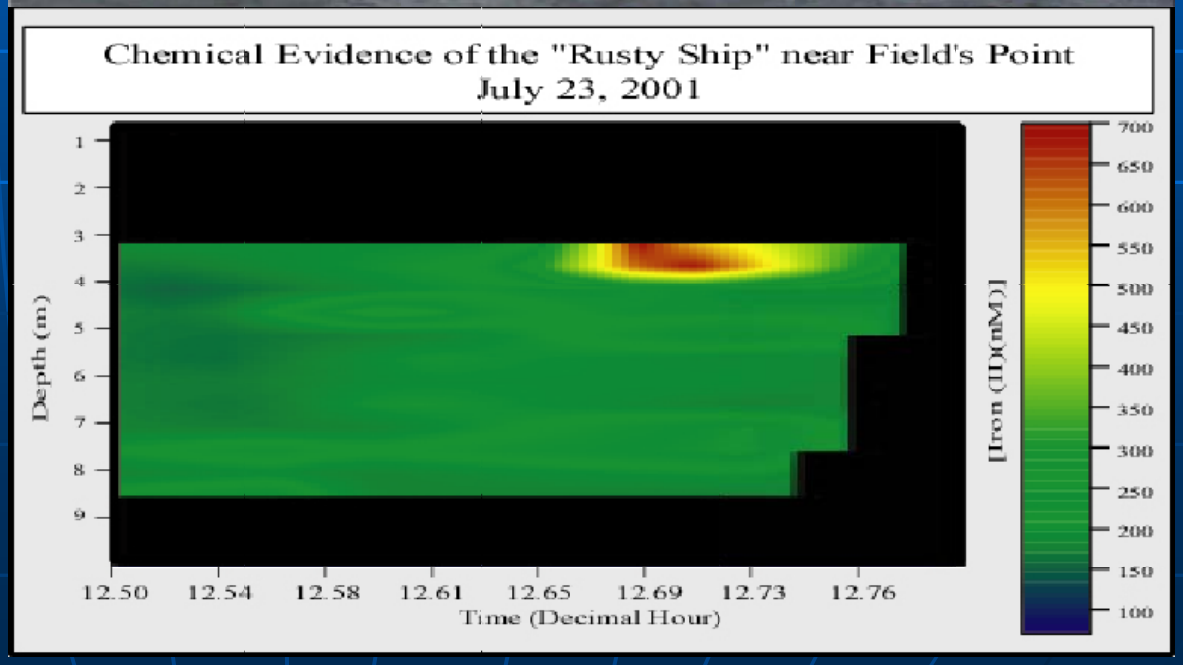
Chemical Plume Mapping with the XZ-Profiler - Undulating Towed Vehicle



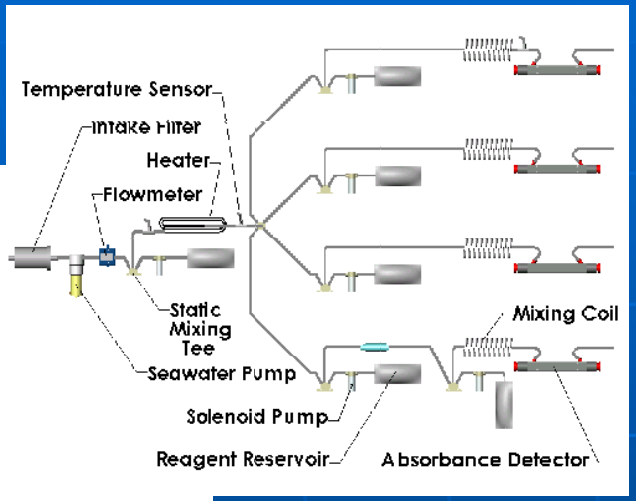


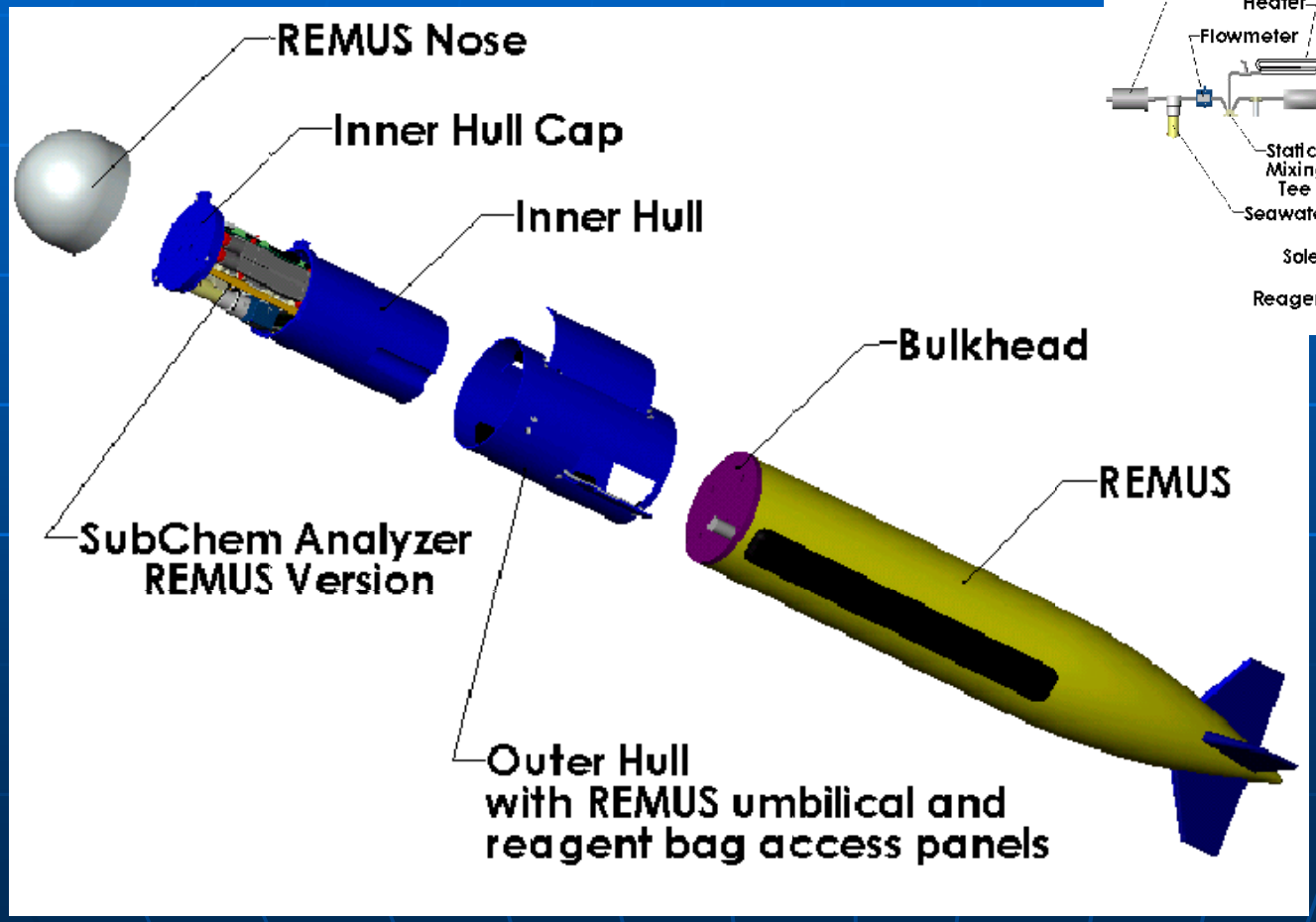
Chemical Plumes in Coastal Waters

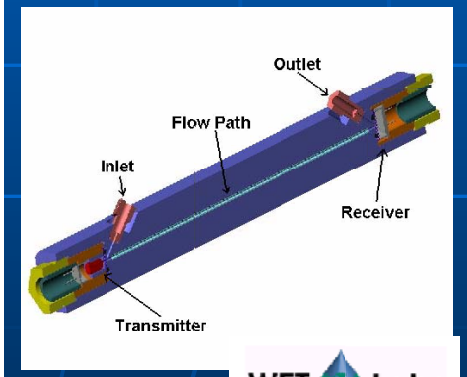
SubChemPak Analyzer
XZ-Profiling System



Sub Chem Analyzer for REMUS







WET Labs
ChemStar

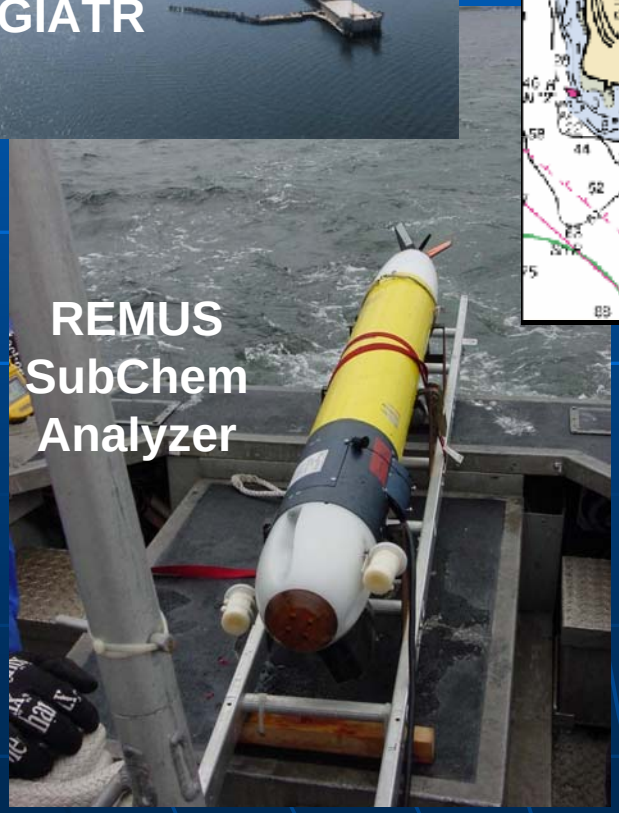
SubChem analyzer payload on REMUS

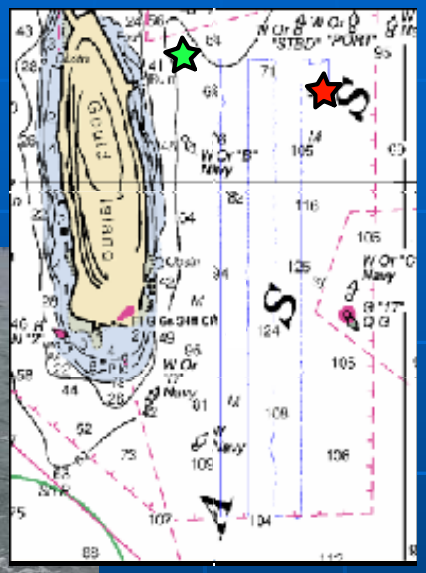
- Four channel analyzer
- Fast response
- Trace concentrations
- Multi-chemical capability
- High resolution mapping
- Real time data display
- ACOMMS AUV control

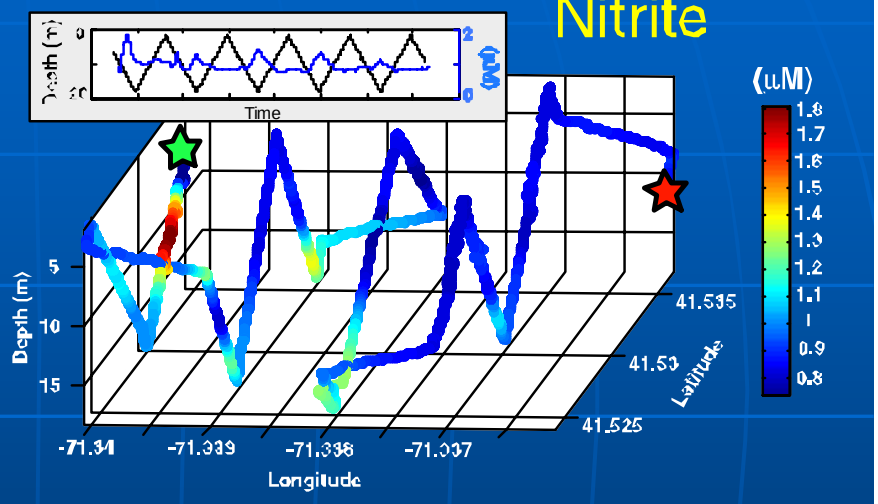
It is expected that this 3-D nutrient mapping capability will be useful for specific scientific opportunities, such as examining the influence of turbulence on fine-scale nutrient availability or for tracking and mapping nutrient plumes or gradients to their source.

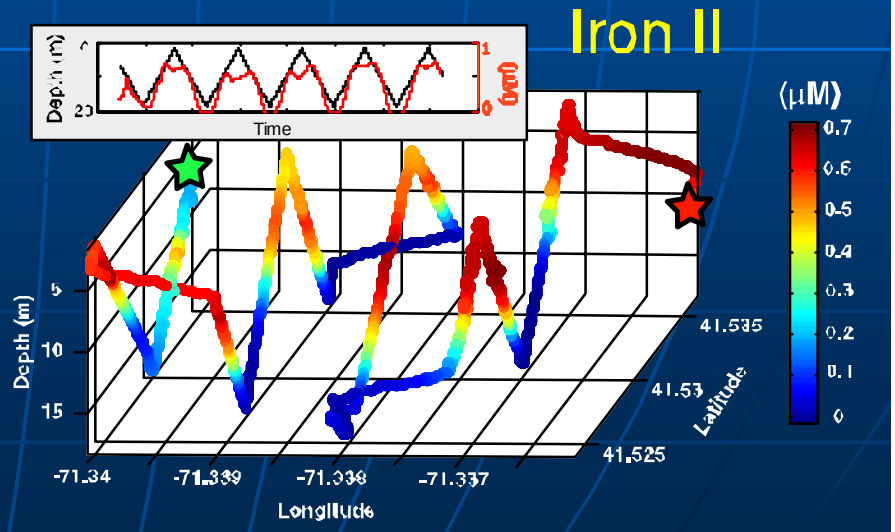
Chemical Plume Mapping with REMUS

NUWC/NPT Gould Island Acoustic Tracking Range

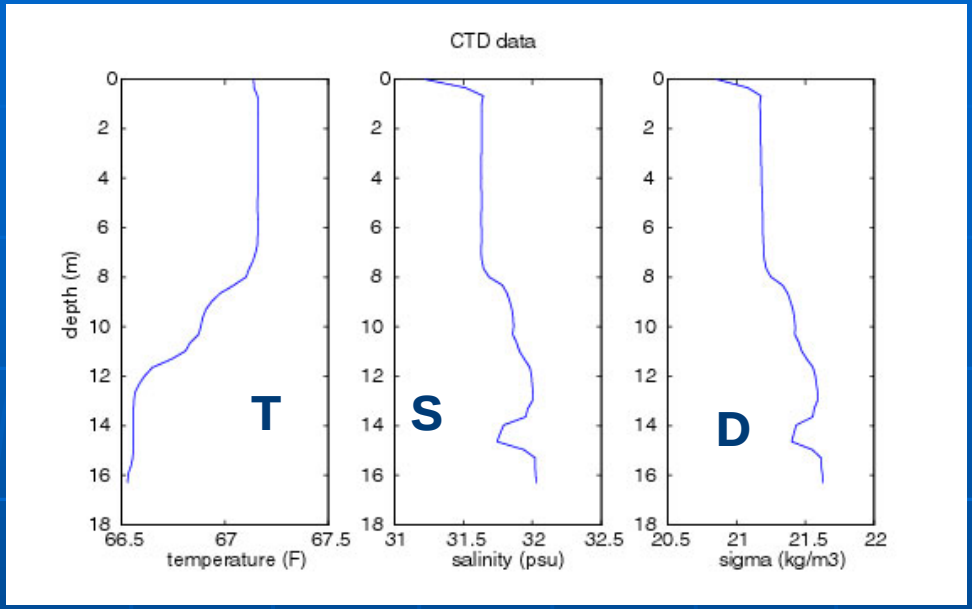


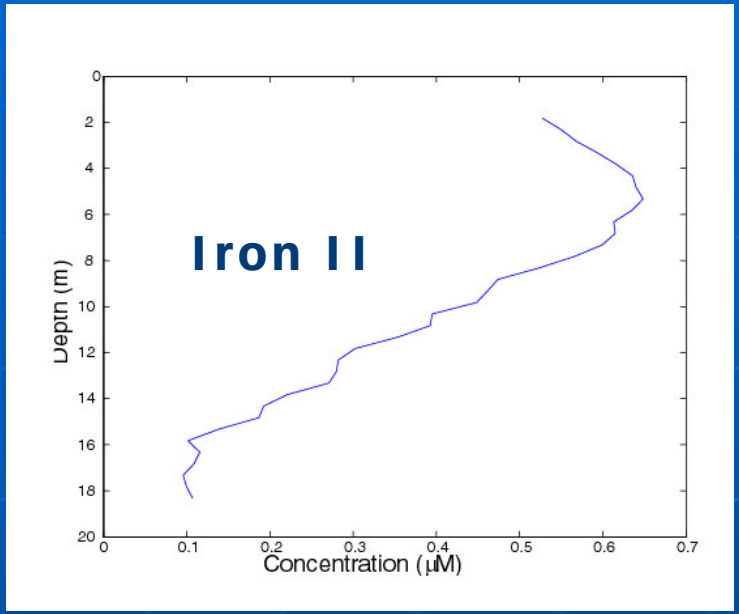


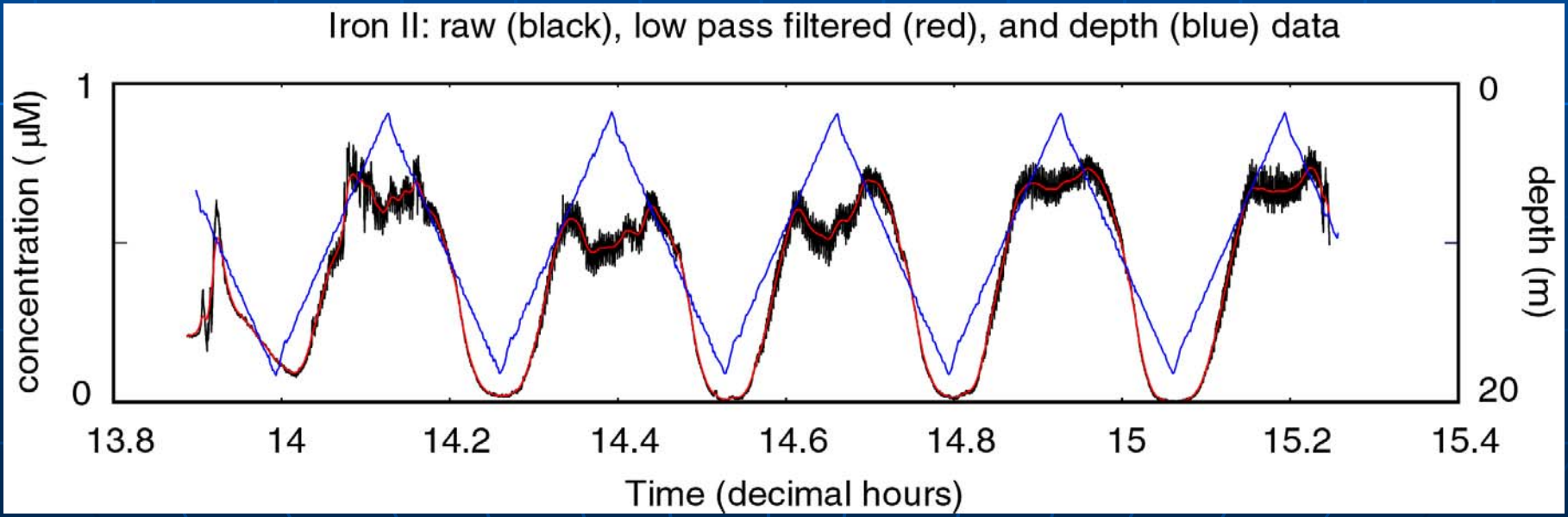




SubChem - REMUS UNDERWAY Iron(II) DATA



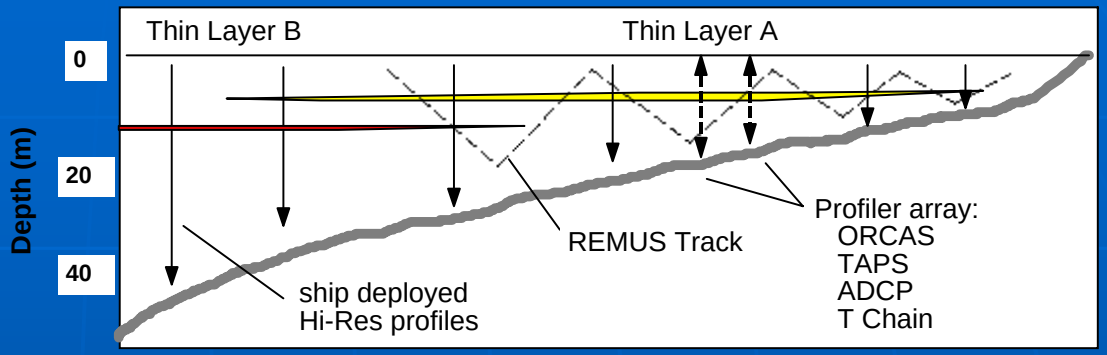


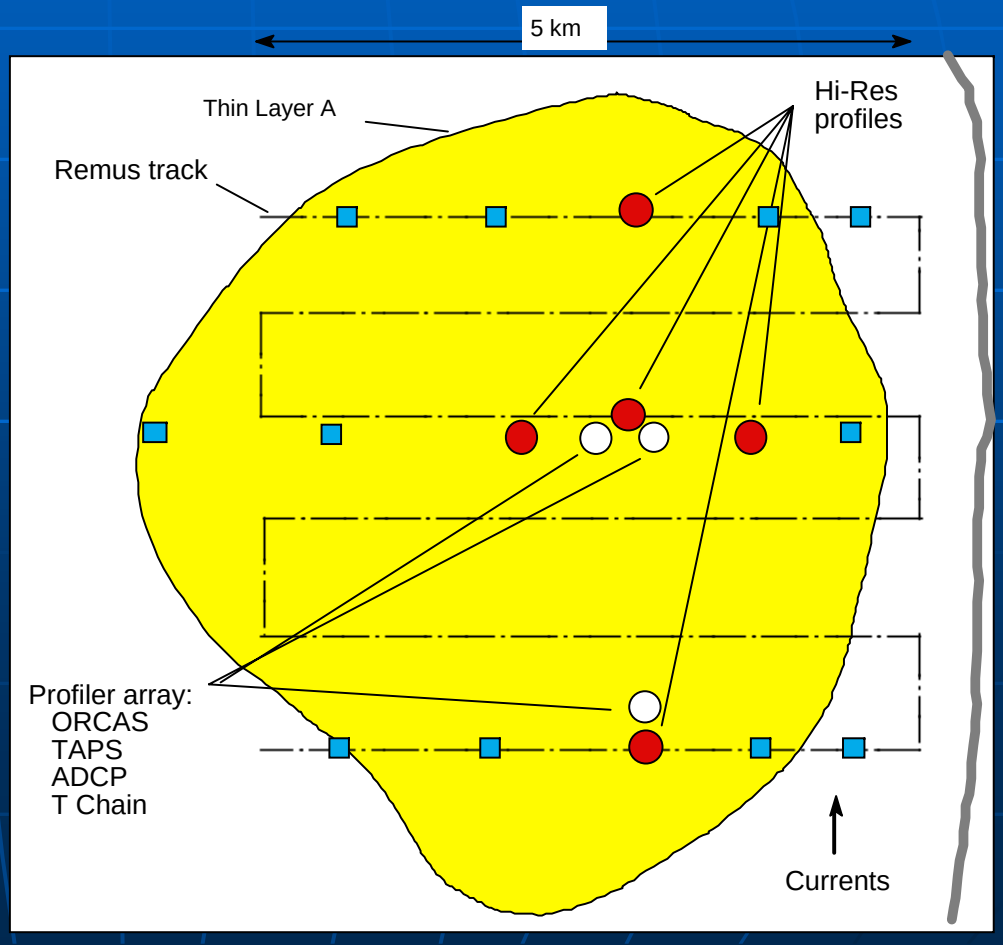


Layered Organization in the Coastal Ocean (LOCO)

The Role of Nutrient Gradients in the Episodic Formation, Maintenance and Decay of Thin Plankton Layers in Coastal Waters

Fieldwork Summers 2005 and 2006 in Monterey Bay





Office of Naval Research

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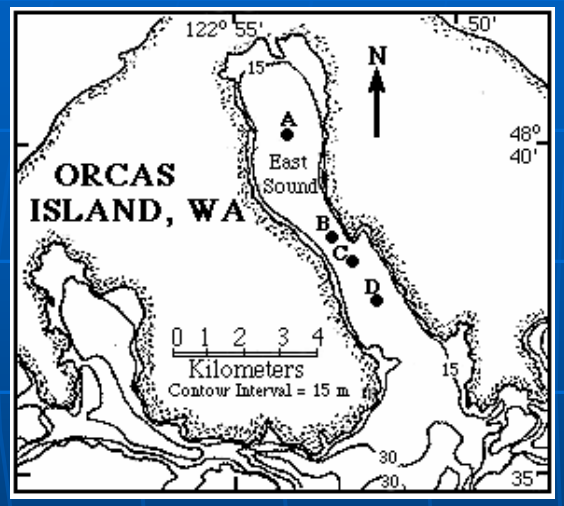
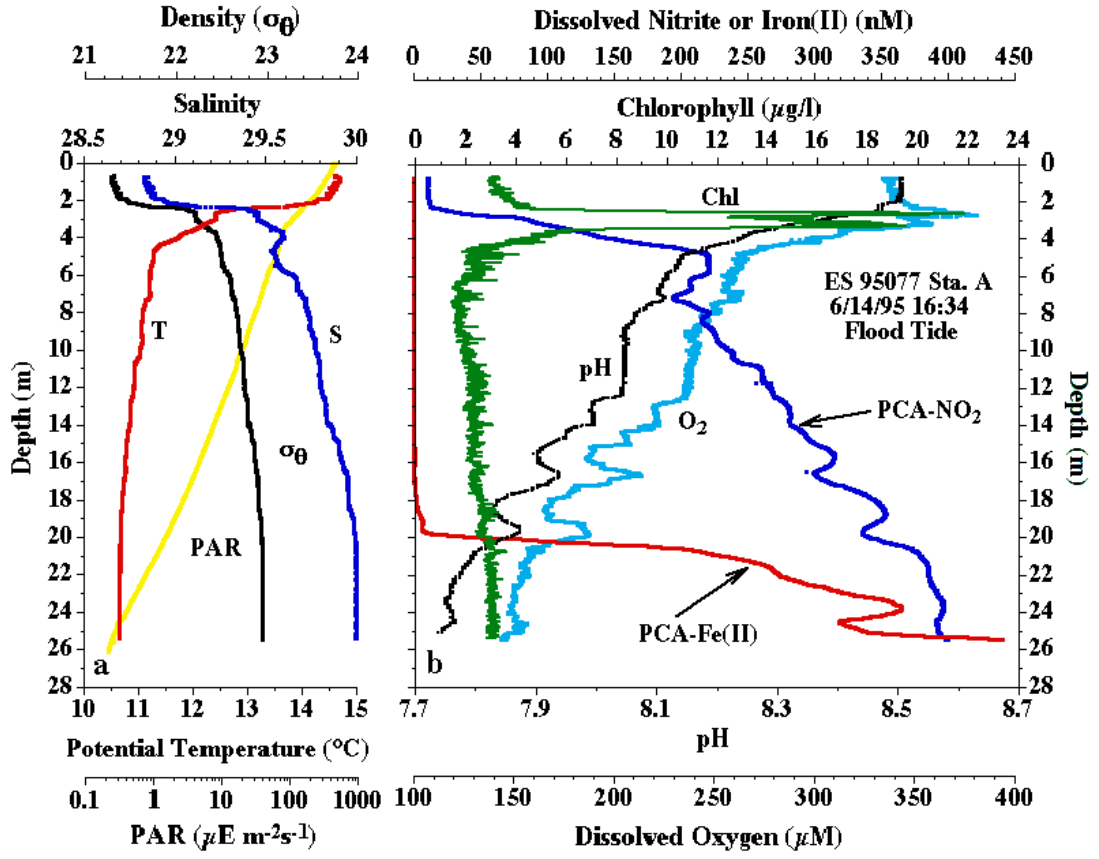
Thin plankton layers, steep nutrient gradients and fine-scale chemical variability in East Sound



(Hanson and Donaghay, 1998).

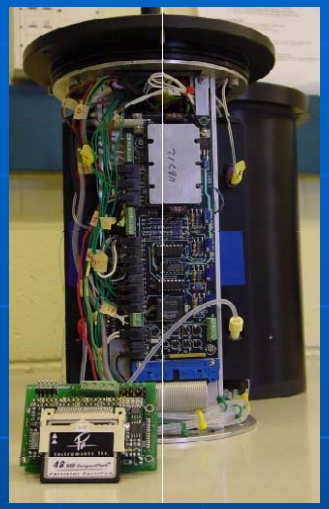


HYPOTHESES

- **Episodic variability in nutrient gradients, driven by and coupled to dynamic meteorological and physical mixing processes, is critically important to the development, persistence and behavior of thin plankton layers in coastal waters.**

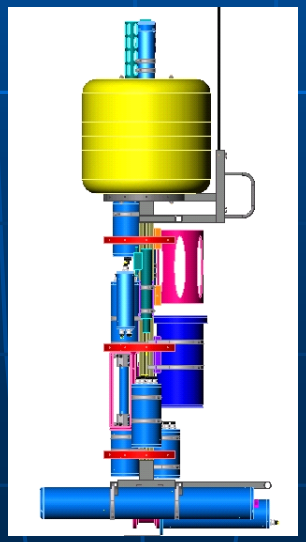
- **Thin plankton layers exert a substantial influence on the fine-scale distribution of dissolved chemicals and on their biologically mediated reaction rates within coastal waters.**

APNA for the URI IOPC Profiler



- Multi-channel analyzer
- Autonomous Profiling
- NO3, NO2, PO4, NH3
- 2-4 week duration
- Nutrient data telemetry

URI
IOPC Profiler
(with Donaghay group)
for ONR fieldwork on
thin plankton layers



SUMMARY

- A series of submersible chemical analyzers have been developed and are being utilized for the measurement of a variety chemicals from multiple oceanographic platforms.
- The novel electro-fluidic and optical detection technologies enable high-resolution chemical sensing in real-time at trace concentration levels.
- The submersible analyzer technology is being adapted for cabled shipboard deployments on vertical profilers and towed vehicles and for remote deployments on AUVs, Gliders, moorings and moored profilers.

Acknowledgements

- SubChemPak Analyzer (ONR-NOPP and CICEET)
  (with P. Donaghay and others and with J. King)
- SubChem Analyzer for REMUS (NUWC and ONR)
  (with J. Miller, and several OE students)
- APNA-IOPC Profiler (ONR-NOPP and ONR LOCO DRI)
  (with P. Donaghay and GSO student R. Sweetman)