Adaptive Sampling in Ocean Observation

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Outline

• Adaptive sampling = Adapting sampling strategy based on observations, to make observations more effective and efficient.

• Brief review of adaptive sampling for moored instruments

• Adaptive sampling for autonomous underwater vehicles (AUVs)
  o Capturing peak-chlorophyll water samples in a phytoplankton thin layer
  o Tracking an upwelling front
  o Targeted sampling when yo-yoing through distinct water columns

• Towards a synergistic adaptive ocean observing system (cabled observatory + AUVs)
Adaptive Sampling for Moored Instruments

- Increasing sensors’ sampling rate when some oceanographic event is detected, e.g., on detection of internal waves [Irish et al., 1984].

- Releasing profiling floats from a mooring when an eddy passes by [Bower et al., 2009].

From Woods Hole Oceanographic Institution website
http://www.whoi.edu/oceanus/viewImage.do?id=58546&aid=34106
Phytoplankton Thin Layers

MBARI Dorado AUV

Courtesy of Larry Bird and Alana Sherman
An Adaptive Triggering Method for the Dorado AUV to Capture Peak-Chlorophyll Water Samples in a Phytoplankton Thin Layer

Peak detected at a delay, but the peak height has been saved.

Peak signal height saved in a sliding window

Peak-Capture Performance in an AUV Mission in BloomEx in October 2010

$F_{676nm}$ (raw reading). Dorado AUV mission 2010.293.00, starting from 10/20 15:09 (PDT), 2010.
Dorado AUV Used in the 2010 Gulf of Mexico Oil Spill Response Scientific Survey
Dorado AUV Survey Tracks

Bathymetry (m) of the survey area

+ Wellhead

AUV tracks

Ship hydrocasts

Ship track
Dorado AUV Survey Tracks

CF (volts) on sawtooth transects btwn 900 m and 1200 m depths (plan view) in AUV Mission 2010.154.01
Capturing Peak-CDOM-Signal Water Samples Using an AUV

![Graphs showing Transects A to G with depth and CF values.](image-url)
Capturing Peak-CDOM Water Samples

Coastal upwelling in Monterey Bay

SST (°C)

11  12  13  14

Front-Tracking by the Tethys AUV

Tethys AUV mission from 12:12, 4/27 to 15:22, 4/29, 2011 (PDT) in Monterey Bay (isobath (m) contours labeled)

Front location on each of the 14 transects
AUV’s 1st transect through the front. From 12:12 to 17:24, 4/27, 2011 (PDT)

\[ \Delta_{\text{temp}} = \text{Temp}_{5m} - \text{Temp}_{20m} \]
Variation of the front's location (longitude) over time
Targeted Sampling when Yo-yoing through Three Distinct Water Columns (Dorado AUV)

AVHRR data courtesy of Kudela Lab (UCSC) and NOAA CoastWatch
Targeted Sampling when Yo-yoing through Three Distinct Water Columns (Dorado AUV)
Chlorophyll bloom
Vertically mixed upwelled water

Front detection: when horizontal gradient of \( (T_{5m} - T_{20m}) \) exceeds a threshold.

Upwelling detection: when \( (T_{5m} - T_{20m}) < 1^\circ C \) lasting for a number of AUV yo-yo profiles.

Peak-capture algorithm: [Zhang, McEwen, Ryan, and Bellingham, *IEEE JOE*, 2010]
Towards Synergistic Adaptive Ocean Observation: Cabled Observatory + AUVs
AUV Docking

- Autonomous homing and docking
- Batteries recharge
- Data download
- Mission upload
- Vehicle sleep/wakeup
- Code modification & recompile

*Bellingham, Hobson, McEwen, and McBride*
AUV Docking

Bellingham, Hobson, McEwen, and McBride
Summary

• Adaptive sampling techniques are important for both moored instruments and mobile platforms.

• Adaptive sampling algorithms we developed for AUVs have enabled accurately targeted samplings in different water columns.

• On a cabled observatory that incorporates docked AUVs, adaptive triggering/sampling techniques are key to efficient use of the system.
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